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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

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TRANSACTIONS

OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

Vol. XIII. JANUARY TO DECEMBER. 1896.

NEW YORK, January 22, 1896.

The 102d meeting of the INSTITUTE was held this date, at 12 West 31st Street, and was called to order by Vice-President Hamblet, at 8 P. M.

Secretary Pope read the following list of associate members elected and transferred at the meeting of the Council, held in the afternoon.

Name.	Address.	Endorsed by.
CUNNINGHAM, E. R.	Sup't Fort Dodge Light and Power Co., Fort Dodge, Iowa.	B. J. Arnold. A. V. Abbott. W. M. Stine.
EDGAR, C. L.	Gen'l Manager and Chief Engineer, Edison Elec. Ill'm'g Co., 3 Head Place, Boston, Mass.	T. C. Martin. Jos. Wetzler. Geo. H. Guy.
EVANS, EDWARD A.	Acting Chief Engineer, The Quebec, Montmorency and Charlevoin Railway, Quebec, Canada.	Ralph W. Pope. J. Day Flack. Edw. Caldwell.
FRANKLIN, W. S.	Prof. of Physics, Iowa State College, Ames, Iowa.	Ernest Merritt. Edw. L. Nichols. Fred'k Bedell.
GITHENS, WALTER L.	Manager, H. P. Elec. Light and Power Co., 7284 So. Chicago Ave.; residence, 5101 Kimbark Ave., Chicago, Ill.	B. J. Arnold. W. M. Stine. A. S. Hibbard.
IIJIMA ZENTARO,	Assistant, Wagner Elec. Mfg. Co., 2017 Lucas Place, St. Louis, Mo.	A. L. McRae. J. E. Randall. F. G. Schlosser.
LEMON, CHARLES,	Hon. Sec'y for New Zealand for the Institution of Elec. Engineers, Palmerston, North, New Zealand.	Ralph W. Pope. J. Day Flack. Edw. Caldwell.
LLOYD, JOHN E.	Ass't Chief Engineer, Philadelphia Traction Co.; residence, 2008 N. 18th St., Phila., Pa.	F. Uhlenhaut, Jr. Wm. D. Gharky. C. A. Bragg.
MOORE, WM. E.	Electrician and Sup't, The Augusta Railway Co., Augusta, Ga.	A. F. McKissick. A. M. Schoen. J. P. Edwards.

NICHOLS, GEO. P.	Partner, Geo. P. Nichols & Bro., Elec. Engineers and Contractors, 1086 Monadnock Build'g, Chicago, Ill.	B. J. Arnold. Louis Bell. F. B. Badt.
POTTER, WM. BANCROFT,	Engineer Railway Dept., General Electric Co., Schenectady, N. Y.	Chas. P. Steinmetz. A. L. Rohrer. Edw. M. Hewlett.
WAGNER, EDWARD ANDREWS,	Electrician, The Mexican International R. R. Co., Eagle Pass, Texas; residence, Coahuila, Mexico.	W. A. Rosenbaum. Edw. Caldwell. A. L. Rohrer.

TRANSFERRED FROM ASSOCIATE TO FULL MEMBERSHIP.

Approved by Board of Examiners, Nov. 6th, 1895.

BOTTOMLEY, HARRY	Electrical Engineer, Supt. Marlboro Electric Co., Marlboro, Mass.
GARDANIER, GEORGE W.	Electrician, Western Union Telegraph Co., New York City.

Approved by Board of Examiners, Dec. 5th, 1895.

SCHEFFLER, FRED. A.	Stirling Boiler Co., New York, N. Y.
CHASE, HARVEY STUART	Electrical and Mechanical Engineer, New York, N. Y
MERSHON, RALPH D.	Electrical Engineer, Westinghouse Elec. and Mfg. Co., Pittsburg, Pa.
WILCOX, NORMAN T.	Manager and Electrician, Seneca Light and Power Co., Seneca Falls, N. Y.
REBER, SAMUEL	Lieut. U. S. Army, Chief Signal Office, Washington, D. C.
JEHL, FRANCIS	Representative, F. Hardtmuth & Co., 60 Liberty St., New York.

Total, 8.

THE CHAIRMAN:—Gentlemen of the INSTITUTE, it requires no word of mine to introduce the gentleman who is to read a paper to you this evening. You all know him very well, and have heard him before, and I take great pleasure in having the honor to present to you to-night our Past-President, Mr. Frank J. Sprague.

Mr. Sprague read the following paper:

A paper presented at the 102d Meeting of the American Institute of Electrical Engineers, New York, January 22d, Vice-President Hamblet in the Chair; and Chicago, January 29th, 1896, Mr. R. H. Pierce in the Chair.

ELECTRIC ELEVATORS, WITH DETAILED DESCRIPTION OF SPECIAL TYPES.

BY FRANK J. SPRAGUE.

There has been so much written on the subject of electric elevators which is pertinent to the subject, that in presenting this paper I shall make free compilation from others, and, supplementing these extracts with some new matter, I shall by lantern views illustrate some details of the more recent machines, their methods of manufacture, and some steps in their development.

The time has passed when any one can doubt that one of the most important applications of the electric transmission of power, and one in the number and variety of its applications already rivaling the electric railway work which has made such marvelous strides in the past eight years, is that of the operation of all classes of hoisting machinery.

Some idea of the extent of the present elevator business may be gathered from the fact that in New York City alone there are not less than 5,000 elevators of various kinds, more, in fact, than there are street cars, and more people are carried vertically than there are horizontally.

Ignoring for the moment the specific methods of application, and discounting the difficulties naturally met in developing machines to do the duty required in modern office work, not alone the technical difficulties, but those commercial ones naturally met when a new company enters the lists with untried machines against the entrenched forces of existing industries, there was still much of encouragement to be derived from a backward glance at the industrial changes wrought in the last few years,

and to all objections raised there came the natural queries: Is the elevator field, great as it already is, limited to the possible application of a water or steam motor? Is there no wider, no more universal application of power for this class of service than has hitherto been presented? Is the hydraulic elevator the one bulwark to stand up against the assaults of the electric giant? Does it present such fixity of design, unity of purpose, refinement of processes, economy of operation and freedom from accidents as to preclude improvement if using some other power?

Let us look at the record in other fields and ask: Why has the trolley system, born only eight years ago, driven the horse from the street? It involves great initial expense, the conversion, distribution and reconversion of energy. It faced all the powers of conservatism, ridicule and fear. It had to combat the allied forces of the Bell telephone interests tested by court action in over twenty States. It had the opposition of the strongest municipal and corporate influences. Every detail of the system had to be created, and yet it stands to-day unrivalled in its industrial progress.

Why is the same trolley system driving the cable to the wall, and why has its adoption marked the abandonment of a plant costing not less than $3,000,000, in the city of Philadelphia? Are there many more examples of the direct applications of force than the cable system, many closer connections between a great engine built for the highest economy and that which it moves?

Why is the steam locomotive giving way to the electric motor on suburban service? Is there any more direct example of the application of steam than is presented by a locomotive, the power of whose cylinders is transmitted directly to the drawbar through the intermediary only of a crank?

Why does the best shop practice dictate the abandonment of the slow speed highly economical Corliss engine and the direct application of power by belts and shafting, and adopt the high speed engine and direct-connected dynamo at a central station, with the conversion, distribution and reconversion of energy by a dozen different motors at a greatly increased initial expense? Is it for any other reason than convenience, reliability and economy of operation?

Why has every overhead crane builder in the United States within the past four years absolutely abandoned wire rope, square shaft and hydraulic transmission for the three-motor transmission

which I advocated only nine years ago? It is because it is simpler, because it will cost less, or because it is more economical, more flexible, and because it answers the purposes better than the other and more direct systems?

Why have the great central stations of the country adopted electricity for the transmission of power to the hundreds of industries within the radius of their supply, and into what form of energy is the power of Niagara being converted?

In short, why is the transmission of power in almost every case where flexibility, convenience, economy, efficiency and reliability are required depending upon the electric method, not only in new work, but oftentimes to the replacing of older plants.

The elevator field, indeed, is a large one, and if the system is electric, then, considered from a commercial standpoint, there appears the following possible classes of work:

1st. High speed passenger service where no hydraulic plant is possible because of limited space.

2d. High speed passenger service in competition with hydraulic plants, the electric plant doing equal duty, costing less, occupying less space than the hydraulic, and costing much less to operate.

3d. Substitution of new high-speed electric service in place of old steam and slow hydraulic services in buildings where the limited space and interference with operations will not permit consideration of a new hydraulic plant.

4th. Passenger elevator service in buildings where the loads are comparatively light.

5th. Passenger service in private houses where safety, simplicity and noiselessness are essential.

6th. Freight and special classes of work.

For convenience we may classify elevator work as "first-class, that requiring speeds from 300′ to 600′ a minute," including the first three duties above mentioned, and as "second class," those requiring speeds of from 50′ to 250′ a minute," which include the remainder.

In general, there has been required and developed two kinds of machines to perform these services. The first is the outcome of the increased height of buildings and the demand for high speed and smooth motion, largely regardless of cost of apparatus, space occupied, or cost of operation.

The hydraulic elevator was the result of this demand, and was

the only one that up to a year or so ago was accepted for this service.

It was to meet this demand—by creating an electric elevator which would do the work equally well, if not better, than the hydraulic—that the elevator to be more specifically described, was developed under some unexpected difficulties.

Of course, such a machine must have the speed and capacity of the hydraulic elevator.

It must be absolutely safe.

It should have advantages in the matter of space, and must be more economical to operate.

The second class of elevator work, that which requires lower speeds, is applied to small apartment houses and other buildings where lighter elevator duty is required. This, for a long time, has been fairly supplied by worm gear elevators, and the replacing of the steam engine by an electric motor has enormously broadened the field for this class of machine.

These two machines, however, are not equivalents. They present two distinct kinds of rope movement, two absolutely different methods of control, and two varieties of safeties.

Just here I will briefly outline some of these differences, for they constitute in my mind vital essentials, and are absolutely determinate in their limitations.

The rope movement on the hydraulic is provided by an expanding set of sheaves on which all the ropes are maintained in fixed planes. Four to six ropes can be used on the machine, and six to eight on the car.

The sets of rope can be equalized at the machine, and they have a fixed lead in the hoistway.

The machines can be double and treble decked, and they have absolute limits of mechanical travel.

All of these features are of the greatest importance when dealing with high lifts, large powers and fast travel.

The drum machine, while having a distinct field of its own, and a most useful one, has not a single one of the characteristics mentioned. It cannot well use over two ropes on the drum, and they cannot be equalized at the machine. The lead is a shifting one, and on long lifts this may be as much as from four to five feet.

These particular objections have been met in a type of machine which may be called a cable drum machine, where the drive is by

friction of the rope in the sheave grooves, but in both these machines, the plain drum and the cable drum, there is the very grave objection that there are no fixed limits of mechanical travel which are independent of the armature movement, and on fast speeds particularly, this is absolutely essential.

In the drum machines the driving power is applied through one or more worm gears.

In my own practice on light service, such as house automatic machines, and a low class of freight work, I use a single gear with double ball thrust bearings, and on heavier work, a right and left handed gear generally cut on the Hindley form, to give the fullest amount of gear surface, and with the shafts connected by independent machine-cut spur gearing, which allows the worm gears to be free from each other.

There is another distinction—that of control.

The hydraulic machine is necessarily a gravity machine, using power only in hoisting, its speed on the down side being controlled by the rate of water exit. The machine is, of course, under counter-weighted.

In the drum machine, when there is any attempt at economy, over counter-weighting is generally used, part from the car and part from the back of the drum, the over counter-weighting being approximately equal to the average load.

With these two types of apparatus as precedents, the problem was:

How far can electricity be applied? What are the limitations of control? What the conditions of installation and operation, and to what extent could one type be eliminated?

And the answer is: Both types must be used, but for distinct classes of service.

Taking the drum type and considering electrical control on a machine over-balanced for average service, the load up or down is sometimes with and sometimes against the machine. To control such a machine directly from a supply circuit, (and I cannot seriously consider any other, no matter how ingenious or refined, as meeting general conditions), there is one method only, and that is the use of a rheostat in starting, and the inverse variation of the strength of the shunt field for about a two to one variation in speed. A cumulative series coil is only permissible in starting if variations of speeds are controllable, and in any event these variations are limited. Such a machine is, however, the best for second-class service.

Every one is familiar, of course, with the conditions of ordinary freight work. I might, however, here point out an important branch of this industry, and one which is destined for very wide application, and that is automatic house service, the machine to be controlled without an operator, and so installed as to be as safe as a stairway.

Briefly, such a machine, on my system of working, is equipped with an interlocking switch device on the machine, having a co-ordinating movement with it, and with the controlling circuit in series with a number of door switches automatically opened or closed with the doors. The doors themselves are fitted with mechanical locks, allowing a car to be opened only during a range of movement from 6″ above to 6″ below.

At each floor is a single controlling button. If the machine is at rest, the pressing of a button calls the car, wherever it may be, to the particular floor at which it is wanted, where it automatically stops. When the door is open it cannot be started, and when running, no one else can call it from the floor for which it is destined. The machine also has an additional control in the car, and the safeguards attending its operation are such as to make it safe for servant, nurse, child or invalid.

The development of the multiple screw elevator was undertaken for the express purpose of supplanting in a large way the former standard for high duty office service, and although not by any means an easy problem, either electrically or mechanically, a knowledge of what the hydraulic elevator is, and the variation of the types existing, gave adequate reasons for its attempt.

Let us consider for a moment a hydraulic system, and institute a few comparisons.

It consists primarily of a steam cylinder, or a multiplicity of steam cylinders, working ordinarily under poor conditions of steam economy, that is with a fixed cut-out in the high pressure cylinder of a compound pump, or no cut-off in any cylinder of a simple pump. This element corresponds to the cylinders of a steam engine in the electric system, which use steam expansively with a cut-off varying according to the load, and under pressure conditions which are somewhat better than exist in a pump. It is to duplicate the results of this system of variable cut-offs and steam expansion, that the energies of the various pump builders have been more or less ineffectually bent for a great many years in plain acknowledgement of that defect in their simple and duplex

pumps, the latter of which is common to almost every hydraulic plant of any size in the United States.

It is true that a so-called "high duty" pump with equalizing piston is used on some of the larger elevator plants, but its use has not proven by any means entirely successful, because of the spasmodic nature of the service.

Among the high duty pumps, the flywheel type, such as is used on large water pumping stations has been attempted, but rarely, I may fairly say, with success.

The next element is the water cylinder, which corresponds to the dynamo in the electric system, and on account of the high friction due to the packing, the efficiency of a water cylinder with its valves is not ordinarily equal to that of a dynamo, which with a motor stands to-day the typical example of an efficient energy converter.

The next element is the piping and the tanks, compression or roof, and perhaps an accumulator, into or through which the water is pumped for delivery to the controlling valves of the elevator, and that which corresponds to this in the electric system is its simple wiring, and if a storage battery is used, then this last in conjunction with it.

Any competent engineer knows that, measured by standard practice, a given number of pounds of energy can be delivered to the controlling apparatus of an electric elevator for less pounds of steam, that is, water evaporated, through the medium of no less than fifty combinations of engines and dynamos, than can be delivered to the valves of any hydraulic cylinder through the standard pumps permissible in average elevator service. To be specific, the average water evaporation on a compound duplex pump, which is almost universally used, will in practice, be not less than about 60 to 70 pounds per horse-power of water energy delivered to the controlling valves, whereas the electric combination will easily give the same for less than 40 pounds.

There are exceptional conditions in which a higher economy can be gotten in a hydraulic system, but they are few and are not typical, and under equal conditions the steam consumption in an electric system can be cut in two.

But this is not all. The fact is persistently ignored, although the attempt is made to offset it by recent experiments with a differential piston, that a standard hydraulic elevator uses the same amount of water under the same pressure for every foot of

travel of a car, which volume of water and pressure are determined by the maximum load which has to be carried, although the average load on the ropes, including the excess of car over counterweight, is not over one-third of the maximum. On the other hand, the electric elevator uses, and must use, under normal conditions, current directly proportional to the work, modified in a small degree by starting and slow running.

In short, over and above the friction load of the generating system, the steam consumption in the engines and the generation of electricity in the dynamo, vary with the demand of the elevator machines. It is a system which is of necessity automatic.

On the other hand, the hydraulic system is one of the most flagrant violators of the relation which should exist between demand and supply. It is a system of transmission by water, having at one end a generating plant doing full duty for every foot of travel of its piston, with a variable duty on an elevator car at the other end, and an intermediate straight line water engine with its pipes and tanks taking care of that variable duty, and using the balance of its energy in heating the water which passes through its valves.

Lack of economy, however, is not the only objection to the hydraulic system when looked at from the architect's or builder's standpoint. Until recent developments, these have always been strictly handicapped, not so much perhaps in the matter of cost, but in the internal arrangements of the building as well as in the lay-out of the basement, neither of which could be finally and satisfactorily, if even then, determined, until the particular type of machine had been accepted by the owner, and the contract finally made for it.

Nor has there been either singleness of design or unity of plan of operation. Each maker has had his own form of construction, his special method of control. Every building has brought up a problem more or less new, or at least conditions which had to be seriously considered in determining the elevator service. Horizontal and vertical machines, in basement or shaft; high or low multiplications; long and short, single and jointed cylinders; big and little diameters; large and small sheaves; free and suspended counter-weights; pulling and pushing machines; direct and differential pistons; roof tanks, stand pipes, accumulators and compression tanks; high and low pressures; hand rope, wheel or pilot-valve control; simple or compound pumps—all

have made a nightmare of complications, giving more initial and continuing source of complaint and dispute than all the other engineering problems in a building.

So what more natural than that they should turn to electricity for emancipation? And this tendency is augmented by other reasons.

Leaving out central station supply, always, when properly equipped, to be preferred when the electric service is of a spasmodic or limited character, and considering for the present those large plants which characterize the modern office or hotel building and in a way rival central stations, every engineer knows that the fewer the number of well-proportioned units, the more alike they are, the freer the interchangeability between themselves, and the greater the extent to which any one unit can be utilized, the better the system for power generation and conversion, no matter what its character.

The best modern practice makes a three-unit direct-connected engine and dynamo plant the best for lighting a building. There is an empirical relation existing between the number of lights required in a building as ordinarily designed, and the elevator service. When, in addition to the lighting service, such a building adopts electric elevators, it is not now necessary that it shall add an independent generating plant.

All that is required is that the three units should be somewhat increased in size and, perhaps, one of them preferably divided, the mains all taken to a common switchboard with two-way switches, and every engine and dynamo thus made interchangeable on either the lighting or elevator circuits, and at times both, especially if using a slow acting corrective converter, some of each can be run from the same engine and dynamo. So, instead of five or six units, some water and some electric, the entire generating plant is reduced to a single system consisting of three units of one size, or two of that size and two of a half size, which can be run interchangeably, and one of which is almost always in reserve.

Just here it is well to consider the probable application of the storage battery which, if built with plenty of lead, with large surfaces and for heavy momentary discharges rather than for long time steady discharges, will prove a most important adjunct to elevator service, which, like railway work, is spasmodic in character.

A modern office electric elevator on actual average service requires an expenditure of about one kilowatt hour per car mile of travel for every eight or ten feet of platform area. A car will make from 1½ to 2½ miles per hour, so that a battery of six elevators will run from 9 to 15 miles, although very rarely making over 12 miles per hour. With an ordinary car, say from 30′ to 35′ area, this would mean from 3 to 3½ kilowatt hours per car mile of travel, or say 35 to 40 kilowatt hours for a battery of six machines. Without a battery this would require a 120 kilowatt machine as ordinarily rated, worked at an average of 35 to 40 per cent. load. With a properly constructed battery a 60 or even a 50 kilowatt machine will handle the elevators.

Roughly speaking, a storage battery should be able to stand twice the dynamo rate for from three, to seven or eight seconds, and the dynamo rate for one-half a minute. If it has an hour discharge capacity equal to the dynamo capacity in kilowatt hours, it should be perfectly capable to run the Saturday, Sunday and night service required in an elevator plant without losing more than one-half its charge.

So much for the general conclusions on electric elevators, which are necessarily more or less brief.

To meet the hydraulic machine there was designed and developed what is now known as the Sprague-Pratt multiple sheave electric screw elevator, following the general lines of a tension hydraulic machine in the matter of rope movement, limit safeties and method of control.

The net result has been, that this machine now stands the superior to the hydraulic elevator in that it has its speed and capacity with, if anything, greater safety, and certain advantages in its automatics.

On high lifts it occupies less space; it is more flexible in its application, is more economical to operate, and it is more easily cared for.

General Description.—The machine may be described as the combination of two old elements with one new one, with specific safeties and methods of control.

Briefly, it is of the horizontal multiple sheave type, with a traveling crosshead and frictionless nut driven by a screw revolved by a motor directly connected, and governed by a pilot motor and rheostat.

The general construction consists of a heavy main beam, carry-

ing the traveling crosshead and the lower screw bearing, with special castings bolted at each end, one carrying the fixed set of sheaves, and the other the thrust bearing, brake and motor. The regulating apparatus is independent and self-contained, and is placed on the wall. From the car to the system of multiplying sheaves the direct multiplying machine and the horizontal hydraulic elevator are practically the same. The crosshead, however, marks the point of departure in the two types.

In the hydraulic machine, this crosshead is rigidly attached to the end of a rod which terminates in a piston moving in a cylinder having an inside length equal to the lineal movement of the crosshead. This cylinder in the vertical type of hydraulics varies from 30 to 50 feet in length, with from 2 to 12 sheave multiplications, and in the horizontal types the multiplication runs as high as 14, with corresponding diminution of length of cylinder and increase in cross-section. Whatever the gearing, however, the length of cylinder is a function of the car travel. In this electric elevator, the crosshead being moved along a screw, stationary so far as the lineal movement is concerned, there is, with any given number of sheaves—only one variable—the length of screw; and, for all heights above about 100 feet, the electric machine has an advantage in matter of length, which, with increased rises, becomes of great importance.

Looking to the needs of office buildings, there has been adopted two methods of rope multiplication, determined by the height of building, and so selected that the length of machine over all, shall not exceed about 30 feet for rises approaching 300 feet actual car travel. From this the length grades down to about 21 feet, so that all rises between 60 and 300 feet can be taken care of with an extreme variation of nine or ten feet in the length of machine, and there is thus provided limiting dimension data of great convenience and utility.

These systems of multiplication I may term direct and indirect. In the former, the entire multiplication, varying from six to ten, is done at the machine, and the ropes lead from the end sheaves over the shaft sheaves direct to the car. A free counterweight is used, the ropes being fastened to the car frame. In this method, which is that common to all horizontal and to many vertical hydraulic machines, the hoisting and counter-weight ropes have unequal duty; furthermore, the ropes having the maximum bending, travel on the outboard sheaves at the same speed

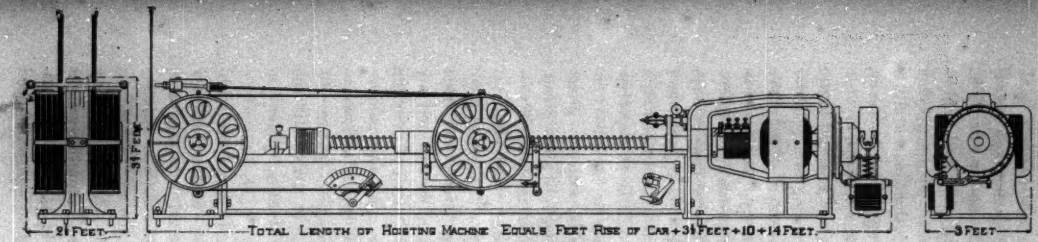
31 Feet
2½ Feet
Total Length of Hoisting Machine Equals Feet Rise of Car + 3½ Feet + 10 + 14 Feet.
For rises of over 200 feet take one half .. .. + ...
Speed of Car with Lbs Live Load = Feet per minute.
3 Feet

FIG. 1.—Type E, 10 to 1 — 4 R. 10 to 1 = Travel Ratio of Car to Nut = 10 Sheaves. 4 R Signifies Four Hoisting Ropes.

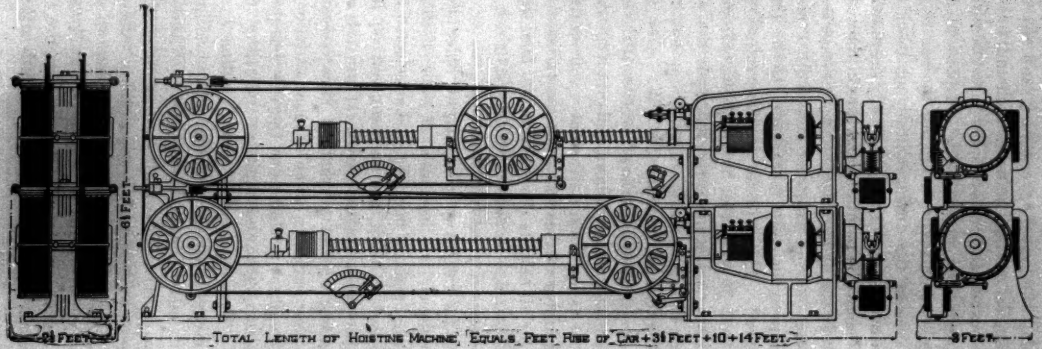
6½ Feet
2½ Feet
Total Length of Hoisting Machine Equals Feet Rise of Car + 3½ Feet + 10 + 14 Feet.
For rises of over 200 feet take one half .. .. + ...
Speed of Car with Lbs Live Load = Feet per minute.
3 Feet

FIG. 2.—Type F, 10 to 1 — 4 R. 10 to 1 = Travel Ratio of car to Nut = 10 Sheaves. 4 R Signifies Four Hoisting Ropes.

as the car. This last is the case also with all vertical hydraulics. In some of the latter, the counter-weight is carried in the cylinder on the piston, or in the strap, or both, its weight being as many times that of a free counter-weight as there are multiplications. Sometimes both methods are used.

Economy of operation and smoothness of movement, however, are antagonistic in their relations to the amount of counter-weight carried. The best method is probably that used when there is a single multiplication in the shaft, giving a two to one counter-weight traveling at half speed, and carried by all the car-hoisting ropes, as is done for short-rise vertical hydraulic elevators.

For long rises I have adopted a combination vertical and horizontal machine rope practice, giving even a more compact machine, a longer life of ropes, and better counter-weight results.

In this indirect system there is a division of multiplication, which, while having the same effect so far as speed of car and length of machine are concerned as a high direct multiplication, has an entirely different result in the wear on the ropes and the amount of counter-weight which can be carried without jumping.

This is accomplished by making one-half the multiplication (6 or 8) on the machine, the ropes, properly proportioned, going thence to the bottom of the counter-weight frame, which has a single multiplying sheave on top. The car ropes go over the shaft sheaves, under the counter-weight multiplier, and back up the hoistway, where they are anchored, giving a car speed twice that of the counter-weight. The equalizing chains, used to make the pull of the car with any given load constant at all points of the hoistway, are fastened to the bottom of the counter-weight frame and anchored in the hoistway.

The space occupied by this multiplier is only two or three inches more than by ordinary form of counter-weight. A proportionally shorter screw, fewer revolutions, and sheaves of greater diameter, characterize this type of multiplying machine.

This system seems to be the best yet devised for long rises, for not only do all the car ropes do equal duty, both with relation to the hoisting strain and the counter-weight, but the rope wear must be less, because of the division of speed and multiplication, the necessity of changing only one-half of the ropes at a time, and the possibility or reversal of the ropes on the multiplying machine to get a new wear.

Where space is limited, I use a double decked machine, and in

the new Commercial Cable Building, which is to be 21 stories high, the machines will be treble decked, and about 10½ feet in height.

Details.—Turning now to the detail construction and operation of this machine, there are a number of features claiming special attention, each unique in character, and marking a radical departure from all other elevator practice. These are the nut, screw, and thrust bearing, the brake, the motor and the regulator apparatus.

One of the most interesting as well as important features, and, perhaps, the one which has been most frequently attacked, is the nut system. It joins the crosshead of the traveling sheaves by a conical seat. There is no fastening between the nut and the crosshead, the continual weight of the car always keeping them in contact; and the friction at this point, being greater than between the nut and the screw, enables the latter to transmit a straight-line movement to the crosshead when the screw is revolved by the motor, and also to revolve the screw and drive the motor a a dynamo when the mechanical brake releases the screw to allow the car to descend. These are the normal functions of hoisting and lowering. There are several other distinct functions of this nut which will be described in considering the "safeties."

Continuing the line of transmission of power, the only points of contact between the interlocking nut and screw are by a chain of balls which occupy a number of threads, and enter and leave the ends of the nut through tubes which are connected together so as to make a continuous conduit. This is one of the most vital points of the elevator apparatus, and herein lies one of the most potent reasons of its success—the reduction of friction by rolling instead of sliding surfaces on almost all parts under pressure; for not only is the nut so constituted, being in fact a developed spiral thrust-bearing, but the thrust-bearing at the motor end of the screw is taken on balls and the sheaves are carried on ball or roller bearings.

This nut being a vital part, its development has been most thorough, and a peculiar treatment of steel which has been adopted renders its surface so hard that the wear is very small, and it is well within commercial limits.

So free is the machine from static friction that it is possible to start the car with a very slight increase of current over the normal hoisting current, providing time be taken so that the work

done in acceleration is small to the work of lifting, although that is not the usual practice.

The balls have an average crushing strain of 25,000 pounds each, but the working pressure varies from only 50 to 125 pounds per ball.

The nut system is a compound one, for, besides the working-ball nut there is another, called the "safety-nut," to which I will make reference later, keyed to it, and between the two is a powerful spring under compression.

The screw is a forged bar of high carbon steel with a peculiarly shaped thread, the finished screw having a tensile strength of 700,000 pounds. It passes through the clearance hole in the steel trunnion crosshead, which carries the traveling sheaves, then through the nut, and is carried at the outer end by a fixed bearing.

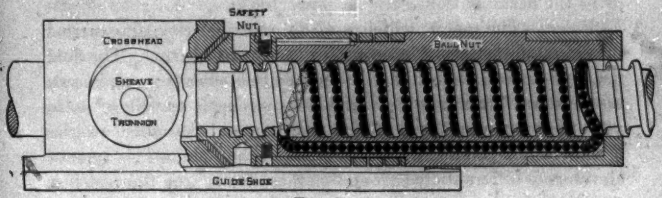

Fig. 3.

This screw is sectioned, being joined to the armature shaft by a cone-seated coupling, secured by a taper gib.

The in-board end of the armature shaft, which is in effect, the extension of the screw, terminates in the thrust-bearing, where the pressure is taken by about 200 steel balls carried in a bronze guide plate and bearing, by specially hardened steel disks. The thrust of the screw being thus taken up on the in-board end, the strain on the screw is invariably between that end and the traveling crosshead—never beyond this; hence, it is always under extension strain—never under compression, and cannot buckle.

The action of the balls on the screw, which is untreated, is peculiar. They form a path for themselves, partly by wear, but principally by rolling compression of the steel, which finally becomes exceedingly hard, such that the edge of any ordinary machine tool would be turned.

The balls themselves wear very evenly. Oblique forms in normal practice cannot exist.

Beyond the thrust-plates is keyed an iron pulley, connected by a flexible coupling with the motor shaft. The function of the brake is that of locking the screw when at rest, it is not a means of varying the speed. In case of accident, it has the additional function of helping to stop the screw. It may be described as a compound electro-mechanical brake. A steel brake band, wood-lined, is anchored at one end, the hoisting-side on the motor-bed frame, and the other end is continually pulled down by a powerful spring under compression. The mechanical movement in opposition is through the medium of a peculiar magnet. It is operated by a dual circuit, one in hoisting, another in lowering. In the event of failure of current for any reason, or too high a speed on the down run, this magnet releases the brake in the latter case by a snap switch, operated by an adjustable Pickering centrifugal governor driven by the main screw—and the brake band promptly grips the brake wheel softly yet powerfully.

Motor.—The motor, which is of the multipolar type, is carried on the same casting which contains the thrust bearing. The field magnets are of steel, and are excited by two circuits; one, known as the shunt circuit, being variable in strength at will, so as to vary the maximum speed of the machine, and the other, a series circuit, which acts to strongly compound the field. This type of elevators is differentiated from all other electrics by the fact that the action is like that of the hydraulic, for it always works against gravity. In hoisting, the motor takes current from the line, but in lowering, its main circuit is cut off from the line, and the motor, rotating in an opposite direction, is driven as a dynamo by the weight of the car. A strong element of safety existed in the fact that the current in the field coils is never reversed, and consequently the machine is never demagnetized. Hence, under certain conditions of the operation of the safeties, it has a power of self-excitation which is of importance.

The armature which turns in this field is of the ironclad type, and not liable to injury of any kind.

It is mounted on a sleeve, is of the 2-path series winding, has a very large commutator, and, of course, multiple carbon brushes. The field coils can be removed without disturbing any other part.

Control.—Considered in its simplest form, and in connection with its action upon the motor and multiplying machine, without reference to the means of communication between the car and the regulator, this last is a very simple device. It is composed of

two parts, each made up of peculiarly shaped iron grids of various sizes arranged in circular form, connected to copper contacts on a slate disk over which passes a heavy carbon brush.

The use of iron castings of a specific composition, possesses great advantage over any form of wire resistance, not alone in the matter of cost. They are flexible, they expand in any direction readily, and, as made, they have a resistance of from forty to fifty times that of copper, or roughly, that of German silver. The grids are interchangeable, and any of them can be readily replaced.

One side of the rheostat is for regulation in hoisting, the other for lowering. Instead of moving this regulator by hand, it is operated by a pilot motor wound with a right and left handed field, one or the other of which only at a time, can be in circuit with the armature. This pilot is connected to the rheostat arm by a single reduction worm gear, and is operated either from the basement or the car, according to the position of the "change over" switch, by an "up" and "down" button with an automatic lever stop which normally has to be held by the operator to prevent the pilot returning to a stop position. The spindle of the rheostat arm operates switches co-ordinating in their movement, in turn controlling the magnetic make-and-break circuit switches, the down brake, and also the automatic stop lever switches which limit the pilot movement.

The use of magnetic switches instead of hand control switches not only removes the arcing from the face of the rheostat, but it gives the benefit of instantaneous cut-offs not possible by any other means of control.

This, on fast machines is of the utmost importance, and the practical application is that if a car is on the "up" motion, and an operator, because of carelessness or because of fright lets go his stop handle, the current is instantly cut off, the regulator following to stop, and the car is arrested in the shortest time practicable.

Assuming that the circuit is made for the up movement, it first meets with a resistance sufficient to about hold the car and lift the brake. This resistance is then gradually cut out, the torsional effort of the armature is increased, giving the car an upward movement with an acceleration depending upon the rate of movement of the rheostat arm, and with a final velocity determined by the point at which the arm is stopped.

If, while hoisting, for any reason the current is cut off, the tor-

sional effort ceases, the brake instantly comes into action and the car comes to rest.

In lowering, the brake is lifted by an independent circuit, but the armature is first short-circuited on itself, and becomes a most powerful dynamic brake. As the resistance in this circuit is increased, the car runs faster. When it approaches the lower limit of movement, an independent retarding circuit is established, and gradually reduces the resistance. This brings the car to the slowest movement.

The pilot movement regulation is, to my mind, an absolute necessity of fast passenger work; and its application, although at first attended with a number of annoying difficulties, is to-day by far the most reliable method of control known.

Safeties.—Of course, the vital question to be considered in any elevator system is that of safety. In that respect, I think, we are amply provided. Safeties may be considered under two heads: First, those on the car, and second, those on the hoisting machine.

On the car we use a special centrifugal which is attached to the lower section of the car frame.

It consists of two long levers, short-fulcrumed at the sides of the car and operating clamping jaws which run in close proximity to the car rails, but normally out of contact with them. The inner ends of the levers overlap, and in action are pressed apart by a very powerful spring under compression. When out of action, these levers are drawn together, the spring is put under compression, and the system locked by a trigger. Near the trigger is a centrifugal governor, operated by a standing rope, which at a determined speed releases the trigger, frees the levers, and the safeties clamp the rails with a pressure of about 16 tons. This safety can be released from the inside of the car.

In the car, as has already been described, there is an automatic stop contact which operates to bring the regulator to the stop position and the car to rest, in case the conductor removes his hand from the controller because of crowding, accident or carelessness.

On the hoisting machine there are a number of safeties. One which is perfectly apparent is due to the fact that the crosshead is moved by a screw with a heavy armature on the end of it, which is driven through the medium of a nut by a car of limited driving capacity. The screw itself is of forged steel, under ten-

sion and torsion strains, with a safety factor of at least twenty to one.

The hoisting nut, as already described, is hardened by a specific process which makes its wear very limited. In addition to this, there is in the nut system what is called a "safety nut." Normally this is out of contact with the thread of the screw, but it is secured to the hoisting nut, and should any accident happen to the latter, breaking its hold on the screw, this safety nut, the threads of which interlock with the screw's threads to a greater depth than the thread of the hoisting nut, would then take the place of the hoisting nut and securely grip the screw. This would put the elevator out of operation because the friction between the nut and screw would be greater than the friction of the traveling crosshead, and it would act simply as a collar on the screw.

The nut system has in addition another function. Since the hoisting nut is only held from revolving by its friction against the crosshead, when the nut gets to the upper limit of its travel the safety nut meets a solid collar on the screw which stops its travel, causing it and the ball-bearing nut to revolve with the screw, without, however, necessarily stopping the motor, and leaving the traveling sheaves to be stopped simply by the weight of the car.

There is still another function performed by the nut system, that of a slack cable device. If for any reason the car in descending, when of course the nut is driven along by the screw, meets an obstruction, the pressure on the nut being instantly reduced, it recedes slightly, allowing the springs between it and the safety nut to expand, throwing the latter into back contact with the screw threads. The nut system then instantly grips the screw, revolves as a collar, and consequently acts as a check against any marked movement of the crosshead corresponding to a free fall of the car on the ropes.

Assuming, however, the condition of a perfectly free release from all operative safeties, there is a limit to the rate of revolution of the screw, and in any event there is a rubber buffer at its lower end which would cushion its stop so as to prevent any injury.

Besides the lower limit switch, which has already been mentioned, which puts an increasing retarding force on the motor, there is an upper limit switch for cutting off the current; this is

a self-cleaning lock switch, operating in both directions, and moved by a roll on the crosshead. It cuts off the current in hoisting in the upper limit, and allows the brake to come on. On the reverse movement it is automatically closed.

I have already mentioned the governor on the machine, which is called a "monitor centrifugal." This is for operating the brake when running too fast. In hydraulic elevators there is no speed-operated device in case of fast running except the centrifugal on the car, and this is frequently set so much above the normal speed on account of the annoyance of having it operated by a temporary excess, as oftentimes to be useless when actually required. The monitor centrifugal does not throw the machine out of operation, but simply slows it up to any desired speed, and then allows the operator to resume control.

The dynamic action of the machine is made use of in still another way by the introduction of an "automatic choking circuit" and switch operated by the same circuits governing the main brake. It is in constant play and closes the circuit around the armature and its series coils through a rheostat under any of the following circumstances: At each stop from up or down; when running down fast enough to work centrifugal on the machine; on failure of the hoisting current, or on failure of the line current.

So positive is the control over the motor, no matter whether it be operating to hoist the car or retard it in going down, that the brake band can actually be removed and the car still controlled, and even with the brake in normal position the change from one position to another can be made so promptly that it will remain inactive.

Such is the machine which has been developed during the past three years, and whose first application in a large battery in the Postal Telegraph Building seems destined to have the same effect on the elevator industry that the plant at Richmond has had on the railway industry. It is only permitted to me, of course, to make the briefest allusion to this, but as illustrating in some degree the extent of this industry, buildings of from five to twenty-one stories in height are being equipped with batteries of from one to twenty-six machines of various types, and the business of a single company employing some two or three years ago a handful of men, now demands a constantly increasing force already numbering nearly five hundred.

Discussion.

The Chairman:—There is no question whatever that the subject which has been before us to-night is one of the most intense interest. Mr. Sprague has shown us what energy can accomplish in a few years, in an entirely new departure in the applications of electricity, and I think many gentlemen present will be glad to learn much more than Mr. Sprague has been able to show us of the subject in the time at his disposal this evening. Are there any questions that gentlemen would like to ask, or is there any discussion?

Mr. Charles P. Steinmetz:—I think you will agree with me, that we have listened to a very interesting paper, and especially have seen some very pretty pictures. There is, however, still another side of the question of electric elevators, that of the central station supplying the power. You all know that no satisfactory lighting service can be derived from a railway circuit. Now elevator work is very similar to railway work. It is greatly fluctuating, the elevator taking at irregular intervals very large power and no power, and therefore it is of very great importance to know how much current the elevator motor takes in running, and how much in starting. If the elevator is run from an isolated plant, it will probably be operated from a special generator; but if an attempt is made to operate it from the same generator as the lighting, and the lights flicker every time the elevator starts, in consequence of excessive current taken by the motor, it concerns only the user of the isolated plant.

When operated from a central station, however, the regulation of the system as a whole is of the utmost importance, and, therefore, the first consideration must be, how much power the elevator motor takes in starting and in running.

I am sorry to see that in this otherwise very extensive paper, no data whatever are given of the amount of current consumed by the motor in running or starting with a given load, although these data would obviously be the most interesting part of the paper for an electrical society. In general, I should expect that the gravity elevator would be inferior, in this regard, to an elevator with over-balanced car, since in a gravity elevator the descent is made without power, and consequently during the ascent the motor has to do twice as much work, and thus probably takes twice as much power as an over-balanced car, in which latter case the motor does equal work during ascent and descent. Furthermore, it would be interesting to know whether any attempt has been made to keep the current in starting within reasonable bounds. Obviously the torque required in starting is greater than in running, and an ordinary shunt motor will therefore take a larger current in starting than during operation at speed; which current, if sufficiently large, exerts a vicious influence on the regulation of the voltage in feeders and mains. For

this purpose attempts should be made to design the motor in such a way that in starting it will consume less current than when running at full speed, and still give more than running torque. It would be interesting to know how the elevator motor described in to-night's paper behaves in this regard, and also how elevator motors manufactured by other concerns act therein.

Dr. Cary T. Hutchinson:—Might I suggest that the remarks of everybody be limited to about three minutes? It is very late.

The Chairman:—The Chair is of opinion that the discussion should be limited to the subject presented by the lecturer of this evening.

Mr. George Hill:—I had taken very much the views expressed by Mr. Steinmetz. To a consulting engineer, employed to pass on the question by an architect or an owner as to the relative economy of an electric or a hydraulic machine, this paper, in its title, appeared to be of very great interest. It seems to me, in view of the fact that the electric elevator industry is more than seven years old; that in this town alone there are nearly a thousand electric elevators in operation, the only excuse for describing a special device, which from my point of view is still of questionable utility, would be that it was so economical as to warrant a description of the machine to show why it is economical. Now we have in the paper that has been read before us this evening, not one word as to the facts of the economical operation of the machine.

I have taken observations, a great many of them; I have installed a great many electric elevators and have watched their operation very carefully. I have ridden on the Postal Telegraph machines a great many times. I have observed the generating plant in the basement of the Postal Telegraph Building. I have ridden on a great many high-speed hydraulic passenger elevators, and, although I am a very strong advocate of electric elevators in their place, I affirm that so far as my experience goes, there is absolutely no machine to-day which can compare with the hydraulic high-speed passenger elevator.

Mr. Sprague:—The gentleman has just said, and here he rather contradicts an assertion made by another before him, that the electric elevator is not, and perhaps cannot be made, the equivalent of the hydraulic elevator, either in the matter of service or economy. It was naturally impossible in the limits of this paper to go into all the details of the operation of a plant, and I much prefer that they should be brought out in discussion. Elevator service is of a distinct character. It deals with large powers; the requirements are the severest. Human life is the stake, and no manufacturer has the right, whether on the score of economy or otherwise, to ignore that vital fact.

The drum machine, which is the only one which can be over-counterbalanced, and which I briefly described to-night, is one which I very cordially and fully recommend for slow speeds and

limited rises; that is, for a service which can be subordinated to the requirements of the machine and a central station. Its manufacture is not exclusive; it is made by my own company and a dozen or more others. When, however, we come to deal with the elevator question as it has been developed by modern practice, and wish to supplant the hydraulic with an electric elevator, then we must surround that machine with at least all the safeties which exist to-day on the hydraulic plant. It must have absolute limits of travel; it cannot be a drum machine with no fixed limits. It must not be subordinated to conditions which may send it into the overhead sheaves or into the basement. The automatics of drum machines can be so disarranged, and certain electrical conditions may arise which will make that machine on fast service absolutely dangerous. It is true, as Mr. Steinmetz has said, that under certain conditions of over counter-weighting a drum machine can be run with less maximum current demands than a gravity machine. That goes without saying; but, taking my own experience, it is fair to assume that there must be a reason for the existence of the multiple screw machine, since I am building it at the same time that I am building machines of other types.

He says the electric elevator of this type cannot do the duty of the hydraulic elevator. Why? Can it not be run as fast? Will it not lift as large a load? Has it not all the safeties which characterize a hydraulic elevator? It has every required attribute of speed, lifting capacity and safety. In fact, it has more safeties than a hydraulic elevator. As an instance, there is not a hydraulic machine in the world which will permit an operator to leave his regulator with the certainty that that car will be brought to an immediate stop. This single characteristic of this type of electric elevator control would, if capable of being applied to the hydraulic machine, have saved the lives of a great many people in the state of New York in the last year.

He raises the question of economy. I am entirely ready to accept any challenge on that score. It comes down to the number of pounds of coal per car mile of travel, the care and attention of machines, and the depreciation of working parts.

There is not an elevator of any kind in the city of New York that averages over one-third of the maximum load on its ropes, because the public rides to suit itself, and not the economic requirements of a plant. A car weighs from 2,500 to 3,500 pounds, and is under counter-weighted so that the net dead weight, or excess of car over counter-weighted, varies from 800 to 1,500 pounds. The car should be able to carry from 2,500 to 3,000 pounds without being stalled; yet there are very few hydraulic elevators, unless over-pressured, which cannot be stalled by loads which it is possible to put in them. We have never yet stalled a screw electric elevator by any load which it has been required to carry.

The average live load on an elevator is not over 500 or 600 pounds, so that, including the excess of car over counter-weight, the net average load on the ropes is not over one-third of the maximum. Whence goes the energy representing this difference? Heating water in the cylinders. Can it be overcome? The attempt has been made to use a differential piston on one of the largest plants in this city. From an economic standpoint it is an absolute failure, for on the particular plant I have what I believe to be reliable information to the effect that they are using at least four times the coal originally guaranteed.

On another modern plant on which the differential piston is not used, the equivalent work is the pumping of nearly two and a half tons of water a distance about 40 feet greater than the run of the car for every trip, full or empty. Does that represent economy?

On another building in this city, the conditions originally set forth, if followed out by the particular hydraulic system, would require the lifting of a piston and sheaves weighing over 20,000 pounds a distance half the height of the building for every trip of the car, full or empty.

And now about the expenditure of power on electric elevators. On cars of the standard size there will not be used over 3½ kilowatts of electric energy for each car mile in actual average service. The electrical engineers in this room can make their own calculations as to what they can develop that amount of energy for.

The coal burned in the hydraulic systems of this city varies from 48 to 110 pounds per car mile of travel.

The coal burned on the electric system, will vary from 30 to 35 pounds per car mile of travel. Are these statements specific enough?

On a recent test in the Postal Telegraph Building, in which six machines were run absolutely without special boiler preparation, but with all the service of the building excepting the elevator, the house pumping and the pneumatic services eliminated by being operated from the street, 1,163 pounds of coal were burned on 46.3 miles' run, including all three services. With 10 per cent. off for pumping, this was the equivalent of 22½ pounds of coal per car mile of travel. There is not a hydraulic plant of equal capacity in this city which can show such a record.

The amount of coal burned is not the only feature to be considered in a hydraulic plant. It costs money to pack the cylinders of a hydraulic elevator, and on fast speeds, high lifts and high pressures this is a serious item, the cost being all the way from $15 to $50 each packing. The good service which the hydraulic elevator has performed during the past years is not a criterion for judging modern high building service, for on such duty cylinders have sometimes been packed as often as every three

weeks for a long period of time, and this can be easily verified by taking the early records in any of the high buildings.

Again, cylinders may pit badly when the water is poor. In the Hotel Netherland, the two main hydraulic cylinders were taken out after a service of practically only eleven months, also an electric drum machine, and the cost of the changes could not have been less than $10,000. It is an exceptional case, and an unfortunate one, but all the same it existed.

The wear on the electric elevator, corresponding to the packing of the cylinder on the hydraulic elevator is on the nut, screw and thrust bearing. Now these screws are not things of very grave cost, but if they wear five or six years, as they will, the annual depreciation, measured in dollars and cents, is not more than the average cost of a single packing of the hydraulic elevator. The operative nuts will wear equally long, perhaps longer. We have not yet worn out one of our standard nuts.

An external central station is not the only source of electricity. Such a system labors under some disadvantages There may be aldermen to look after, street rights to obtain; there is the cost of distribution, meterage and repairs. Every man knows that a central station, so far as the generation of electricity is concerned, is the more economical, much more so than a local or isolated plant can normally be. There happens to be, however, in all large buildings, a number of problems which have to be considered.

Take, for example, a building like the Manhattan Hotel, which I am equipping. They have their lighting and a distributed elevator service with special problems. Sometimes the guests get cold, and the building has to be heated; sometimes hungry, and their food must be cooked; perchance thirsty, and cooling drinks must be supplied, this last is not the only service for the refrigerating machines. A laundry may find a place in a hotel, and bathing is occasionally indulged in. For all these purposes steam must be supplied. Of course, a man can put in his steam ice machines, and he can put in hydraulic elevators with a pair of duplex pumps, and a roof tank or a pair of compression tanks; he can put in his boilers for doing that work, and for supplying the steam otherwise required, and the lighting problem remains. Then he can go to the street for that lighting, but I should be surprised if a competent electrical engineer would hold that this method of dividing supply is as economical as a system of electric generation with interchangeable units, either three of one size, or two of one size and two of a half size.

Suppose one is operating an office building. What do the tenants get? Their light and the elevator service, heat and ventilation. How much light? All they want. That is the great commercial problem here in New York, when dealing with existing conditions,—the difficulty of using a meter in a building where a man expects his light with his rent, and where he goes

out and leaves all of the lights burning, subject to the will of the cleaners.

Hence a man should generate power in his building for all of the service of the building, or take it from the outside for all the service possible. There is a line of demarcation determined by the size of building and the extent of its service. I fail to see how it can help him to get his lights and steam from outside, and pump his water inside. If he stays inside at all, he would better stay inside entirely.

The practical result is, that in the Postal Telegraph Building the number of lights, the car miles of elevator service, the air pumped, the motor converters operated, and the number of hours of service aggregate more for a given amount of coal than like services anywhere in the city of New York.

It is pertinent to ask: Where is this coal saved? In the lights, which are run according to standard practice, in the telegraph service, which is special, or in the elevator service? Ordinarily, the amount of coal used in a building of this kind for elevator service alone is from 2½ to 3½ tons of coal per day of 12 hours. We can shut off the entire elevator service of the Postal Telegraph Building, and run from the street, and save only an average of a ton of coal in 24 hours, and if a man has to pay a difference of from $6 to $10 a day more for coal for using hydraulic elevators instead of electric, he will find it a continuous interest charge on a rather large investment.

I trust I have answered explicitly some of the questions as to the matter of economy, but if those answers are not definite, I will make them more so.

Mr. Hill:—Now let us have the facts. Mr. Sprague says he has lots of them. Let us have those facts added to his paper, and then we will see how they compare with other facts obtained absolutely impartially, and then, if he is right, I will admit it as quickly as anybody.

Dr. Charles E. Emery:—Independent entirely of commercial considerations, or the merits and demerits of hydraulic and electric elevators, I will say that personally I am very much obliged to Mr. Sprague for his lecture to-night and for an opportunity to see in detail his admirable apparatus—admirable in design, wonderful in execution. I think that there are many here much of the same mind, and therefore move that a vote of thanks be tendered the lecturer of the evening.

Mr. Hill:—I second the motion, Mr. Chairman.

The motion was carried.

Mr. H. Ward Leonard:—As regards the question of power required for starting, and as regards the question of economy in operation, those are the two principal points which I personally have been giving attention to, in connection with methods for operating electric elevators. I have not had anything particularly to do with the practical development of ideas of my own which I

have spoken of before on this floor. But they have been used by the Otis companies, and plants have been installed which are exactly on the lines of the method of control which I have described to you. This method of control, as you may remember, is one in which—in the case of an isolated plant such as an office building—a generator is in operation for each elevator that is to be run, and the fields of the generator and the fields of the motors are excited from the lighting circuit. I agree with Mr. Sprague in his statement that the power for these electric elevators in large buildings will be obtained from isolated plants, and that there will always be a lighting plant in a building of that nature from which the current can be taken for the excitation of the fields of the motor on my system of control. A plant having three elevators of this nature has been installed in this city which has been recently tested. They are drum machines, and were tested at an operating speed of 450 feet a minute. In starting, the power required is something less than 15 horse-power. As to the water consumption, the Otis company is prepared to guarantee 150 pounds of water per car mile run. The elevator stops by the production of electric energy by the elevator motor acting as a generator, and furnishing its current back to what was formerly the generator, working it as a motor, tending to accelerate the engine. This amount of energy is really quite a large factor, it is no theory. It is an apparent and important factor in the economy of operation. The plant is simplicity itself, as compared with the very ingenious methods and devices which have been shown us to-night, as it has merely a standard shunt-wound generator and a standard shunt-wound motor, and a drum and worm, with an attachment on the elevator drum by which a travelling nut inserts a resistance automatically at the top and bottom of the elevator excursion, to automatically stop the car in its motion. The stop is peculiarly smooth because of the fact that no mechanical brake is used, and the energy, which in the case of the elevator described by Mr. Sprague is used somewhat for braking by using the energy produced by the elevator in its stopping, is in this instance not merely electrical energy produced and then wasted in a rheostat, but a large portion of it is saved as it becomes usefully stored in the energy of the fly-wheel of the engine and becomes available later for operating the elevators. In the case of elevators working on this plan, when operating from a central station, there is between the elevator itself and the source of supply a rotary transformer of energy, which means a mechanism which combines a motor armature and a generator armature. An elevator operating on that plan will entirely eliminate the difficulties mentioned by a former speaker, due to starting elevators upon the Edison three-wire system, which does require a close regulation of pressure on the lamps. There are plants of that nature which have been running two or three years, and there is this to

be said about some ten plants that have been installed on this method of mine, and that is that, so far as I am aware, and so far as I can learn, not one has ever had any portion of its plant replaced on account of breaking, or accident, or wearing out, or from any other cause.

THE CHAIRMAN:—The Chair will announce the discussion closed.

MR. C. O. MAILLOUX:—I would like to hear this discussion prolonged, though not this evening, perhaps. I myself came a long way to hear the discussion, and it is a subject of too much interest to be closed immediately. There may be other statements that other people might want to advance and discuss, and there is a great deal to be said in relation to electric elevators. I might wish to say something myself.

THE CHAIRMAN:—What is the sense of the meeting?

MR. HOLMES:—I move that the discussion be extended half an hour.

MR. HILL:—Before you put that motion, Mr. Chairman, I like to move an amendment to it—that the discussion be deferred to the next meeting.

[The motion as amended was carried.]

THE CHAIRMAN:—Before we adjourn, I have a request from Mr. Steinmetz to read a short communication. I presume he will be very short.

[Mr. Steinmetz read a communication.]

THE CHAIRMAN:—What action will the INSTITUTE take on the communication of Mr Steinmetz?

MR. TOWNSEND WOLCOTT:—Is that in the definite form of a motion?

THE CHAIRMAN:—It is a communication to the INSTITUTE. It is open for action. A motion is in order in regard to the communication.

DR. F. B. CROCKER:—I move that it be referred to the Council, where it should have been sent in the first place.

[The motion was carried.]

Adjourned.

DISCUSSION AT CHICAGO.

THE CHAIRMAN [MR. R. H. PIERCE]:—We are all very much interested in this paper, and we consider ourselves fortunate in having Mr. Arnold, who has considerable knowledge of the subject, to explain it to us. I think that all of us have a great deal of admiration for Mr. Sprague, for we all know the energy, and courage and ability which he has manifested in electric street railway work, and I have no doubt that he is equally efficient in electric elevator work. He was a pioneer in making the electric street railway a success, and he has in the paper brought out a number of good arguments in favor of electric elevators for high

class work to replace hydraulic elevators. Whether or not we agree with Mr. Sprague in all his conclusions, we certainly owe him considerable deference, and ought to respect his judgment, as he has shown himself in the past to be a pretty good authority on similar lines of work. We probably will not agree to many things in this paper. Many statements are made in regard to the inferiority of hydraulic and steam elevators, and some of these we will not assent to. The only thing we have to regret is, that the paper covers so much ground that we are unable to let Mr. Arnold explain it as fully as we would like to have him do, or to go into a discussion such as the paper is worthy of. However, let as many as possible give us their views of this paper to-night, and make what criticism, or ask what questions they can in our limited time.

MR. FRANK B. RAE:—I am not prepared to discuss to any large extent, the paper which has just been presented to us. I think, as our Chairman says, that Mr. Sprague is entitled to a good deal of the credit for the development of the electric elevator. There are a number of things about the Sprague machine which I would like to know more about, before expressing any very decided opinion. There are a number of things connected with this machine, which I am at present inclined to question. The controlling device is one thing which I would like to be more familiar with, and somehow, I cannot reconcile myself to Mr. Sprague's methods in this machine by which he attempts to reach hydraulic practice. I agree with him that it is a good thing to have a mechanical limit to the travel of any machine. It is perhaps necessary to go to to this kind of a machine in order to obtain that limit of mechanical travel.

I would like to have Mr. Arnold tell me the necessity for the large starting currents. Is it altogether necessary that these should be used in the time that acceleration is required to get this machine to speed? There is a reference in Mr. Sprague's paper to kilowatt-hours per car mile of travel of the car. He tries to reduce it to something like the car mile of the street car. I do not see how he arrives at the cost of operation in that way. As I understand it, he makes so many feet, or so many miles of car travel for so much cost of power, without any reference whatever to the load that he carries, or the number of stops that he makes. It seems to me, that the number of stops and starts that are made in the elevator car travel would have a great bearing upon the cost per car mile. It certainly is a fact that you can lift a given load at a given speed with a given expenditure of energy; with a hydraulic machine, or any other, it takes so much energy to lift so much weight. The only thing would be that the less load, the less friction there would be in the lifting device. Every time he starts that car and puts it to speed, he must expend more energy than would be required to run it a very considerable number of feet at full speed. I would like to

understand how he arrives at that particular point of actual expense.

MR. B. J. ARNOLD:—In referring to the starting current, there is no doubt that these machines take a high starting current on account of the car not being entirely counter-balanced. We therefore have a very heavy mass which we must accelerate very rapidly. If time was given to accelerate this heavy weight, it could be done gradually with a moderate, current getting it up to speed with a low consumption of energy. It takes a large current, however, to start it quickly, but the objection, such as it is, is largely overcome by the non-consumption of current when the car descends. Many elevators take smaller starting current, but they must use current to descend with, resulting in an equally high, if not higher, average consumption of current per foot-pound of live load carried, than is consumed by the machine under consideration. I have had occasion recently to test three of the leading worm-gear counter-balanced car elevators, and reduced them all to a kilowatt-hour car mile basis.

PROF. W. M. STINE:—Have you investigated the number of stops per mile?

MR. ARNOLD:—Yes, I have a record of the stops. The elevator service in leading office buildings is very similar, so that in taking tests of several plants, you get pretty accurate basis of comparison when reduced to a kilowatt-hour car mile basis.

MR. RAE:—What average of stops would you compute per car mile? Does not every start of the car, does not the number of times you start the car, affect the cost per car mile? What is the average number of stops you are going to allow to the car mile? In considering this car mile cost, the energy expended in starting and accelerating the load, seems to me quite as much a part of the problem as operation at full speed, and as this energy expended varies with the load, I cannot see how it can be determined, except for each individual machine by test, where the cost should be divided at least into two parts, starting and accelerating, and running at full speed.

MR. ARNOLD:—In ordinary office buildings, the service is so nearly similar, that the relative tests of different machines give fairly reliable results, and on that basis I have made the tests and compared the different costs, taking into consideration the number of feet each car travels. From these records the energy consumed varied from 4 to 7½ kilowatt-hours per car mile.

PROF. STINE:—To get a correct result, of course you must test at a uniform speed. In taking average service, and that is the only thing you can do, and, at best, your figures under those conditions are not absolutely correct, you cannot get absolutely correct figures on elevator tests. You know they are correct under the conditions in which you test them, but you cannot make a uniform load under which you can make all tests. You do not always get the same basis for comparing the cost per car mile.

MR. NEILER:—May I ask Mr. Arnold if he has any data concerning the hydraulic service?

MR. ARNOLD:—I do not consider that the conditions under which the hydraulic elevator tests were made were very favorable, so it would not be fair for me to state just what the figures were.

MR. STEVENS:—As I understand this paper, one of the main points is the economy of the electric elevator, due to the fact that the motor will adjust itself automatically to the load which the car itself carries, while the comparison is made, that in the hydraulic elevator it is necessary to do the full amount of work whether there be a heavy or light load in the car. Is it not a fact, that the actual work for the varying load of the car is so small a feature in the amount of power required in each case, that it would be rather in favor of the hydraulic elevator.

MR. ARNOLD:—No! I think the variable load gives the electric elevators a distinct advantage. In the average hydraulic elevator plant, there is required from 70 to 100 pounds of steam per horse-power hour of work, delivered to the car, while in an electric elevator plant, the same energy is given to the car by the consumption of about 40 to 50 pounds of water, thus effecting a large saving in the fuel required to evaporate the water at first. Again, the electric elevator service has all the advantages that are claimed for an electric street railroad, when being operated on a variable load, viz.:—The absorption of power in direct proportion to the live work done; consequently the variation of the live load enters very largely into the efficiency of the plant.

The point so well brought out by the author of the paper, that as all large buildings now have an electric plant, the electric elevator becomes merely an adjunct to the main plant instead of a distinct plant itself, as in case of the hydraulic, should commend the electric elevator side of this question.

MR. STEVENS:—The hydraulic elevator is usually able to stand side by side with the electric elevator, if the correspondingly advanced ideas of machinery are put in. Very little engineering ability, I think, has been used in putting in pumps for hydraulic elevators. I think a change in the pumps in many of the buildings would increase the efficiency of the plant at least 40 per cent.

MR. ARNOLD:—I think we will find a very marked economy in favor of the electric elevator, even when we get there.

MR. ALBERT SCHEIBLE:—At the Auditorium Annex, in this city, there were some tests made of the hydraulic elevators, count being taken of the number of persons in the car, the number of stops made, and the number of starts, and the steam and water consumption. These tests were made for comparison with some of the Sprague and other papers.

Adjourned.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

NEW YORK, February 26, 1896.

The 103d meeting of the INSTITUTE was held this date at 12 West 31st street, and was called to order by President Duncan, at 8 P.M.

The President:—The first business before us to-night, after Mr. Pope has made some announcements, is on the motion to incorporate the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

The Secretary read the following list of associate members elected and transferred at the meeting of Council in the afternoon.

ADAMSON, DANIEL,	Manager, John Adamson & Co., Hyde, Cheshire, England.	Chas. F. Sise. Henry Jackson. C. A. Carus-Wilson.
BADEAU, ISAAC F.	Ass't to the Engineer, Met. Telephone and Tel. Co.; residence, 213 W. 121st St., N. Y. City.	J. J. Carty. T. T. P. Luquer. H. Loewenherz.
COLLETT, SAMUEL D.	Engineer Construction Dep't Met. Telephone and Tel. Co., 18 Cortlandt St., N. Y. City; residence, Van Pelt Manor, N. Y.	John W. Howell. J. J. Carty. U. N. Bethell.
DECKER, EDWARD P.	Electrical Engineer, Met. Telephone and Tel. Co., 18 Cortlandt St., N. Y. City; residence, Van Pelt Manor, N. Y.	J. J. Carty. U. N. Bethell. Herbert L. Webb.
FOSTER, SAMUEL L.	Electrical Engineer, Market St. Railway Co., 19 Hobart Bldg; residence, 839 24th St., San Francisco, Cal.	F. E. Smith. J. A. Lighthipe. Louis M. Clement.
GRIFFES, EUGENE E.	Senior Partner, firm of Griffes and Sumner, 307 South Main St., Los Angeles, Cal.	Alfred E. Wiener. Leo Daft. Joseph P. Stone.
MONTAGUE, RALPH L.	Chief of Electrical Department, The Gold Dredging Co., Bannack, Mont.	R. W. Pope. W. D. Weaver. Samuel Insull.
REID, EDWIN S.	Sup't of Construction, Standard Underground Cable Co., 18 Times Building, N. Y. City; residence, 116 W. 11th St.	S. D. Field. M. M. Davis. R. W. Pope.

SHARPE, E. C.	Consulting Electrical Engineer, 20 Potomac Block, Los Angeles, Cal.	Chas. T. Lindner. T. A. W. Shock. W. C. Cheney.
SULLIVAN, EDWARD,	United Electric Light and Power Co., 108 Fulton St, N. Y. City; residence. 337 W. 18th St.	N. Tesla. Wm. Maver, Jr. C. C. Haskins.

Total, 10.

TRANSFERRED FROM ASSOCIATE TO FULL MEMBERSHIP.

Approved by the Board of Examiners, January 8th, 1896.

SHEPARDSON, GEO. D.	Prof. of Electrical Engineering, University of Minnesota, Minneapolis, Minn.
SINCLAIR, HENRY A.	Electrical Engineer, The Tucker Electric Company, New York City.
NUNN, PAUL N.	Consulting Engineer, San Miguel Cons. Gold Mining Co., Telluride, Colo.
WINSLOW, GEO. H.	Electrical Engineer, 700 Lewis Block, Pittsburg, Pa.
GHARKY, WM. D.	Sup't Underground Cable Const. and Maintenance, Philadelpia Traction Co., Philadelphia, Pa.
FISH, WALTER C.	Manager Lynn Works, General Electric Company, Lynn, Mass.

Total, 6.

THE PRESIDENT:—I would now ask Mr. Vansize to give briefly the reasons why it is desirable to incorporate the INSTITUTE.

Mr. William B. Vansize read the following committee report and explained the points involved.

This Committee was appointed by the Council at its meeting on December 18th, to consider the question of the "Incorporation of the INSTITUTE and the changes that may be necessary and advisable in the Constitution."

The Committee met on January 8th. After some discussion it was decided that it would be advisable to divide the work of the Committee into two parts, and to consider, first, the incorporation of the INSTITUTE; second, the necessary and advisable changes in the Constitution. This was deemed necessary, since the meeting that will be called to vote upon incorporation, must vote unanimously in its favor in order that the action may be valid.

Your Committee believes that it will be greatly to the advantage of the INSTITUTE to be incorporated, and recommends that the necessary steps outlined below be taken to make this change.

A voluntary association, such as the INSTITUTE now is, has no standing before the law and cannot receive bequests or hold property. Every member of such association is individually and jointly liable for all debts incurred by any agent of the association.

A corporation, on the other hand, has a standing before law, it can acquire property by grant, gift, purchase or bequest and hold and dispose of it for the purposes of the corporation. The ultimate liability for debts, for which a judgment against the corporation has been obtained, and remaining unsatisfied, is limited to the Directors, and is not shared by the members of the corporation individually. This responsibility of the Directors is a limited one, and extends only to such debts as are contracted by the Directors during their term of office and which shall fall due or judgment be had within one year from the time at which they are contracted.

It is therefore recommended that the Council take the following steps in order to submit the question of incorporation to the members of the INSTITUTE.

1st. That the Council pass the following resolutions :

"It is voted that the President be directed to call a special meeting of the INSTITUTE, to consider a proposition to incorporate the INSTITUTE under the Membership Corporation Law of the State of New York. (Laws of 1895, Chap. 559, Section 5.)"

2nd. That the Council send out the following notice to all the members of the INSTITUTE :

"Notice is hereby given that at a meeting to be held on the 26th day of February, 1896, at 8 o'clock in the evening, a proposition to incorporate such INSTITUTE or Society in pursuance of Section 5 of the Membership Corporation Law, will be acted upon by the members thereof."

Dated New York, this day of January, 1896.

MAJORITY OF COUNCIL.

This notice must be sent out at least thirty days before the date set for the meeting to vote upon the question, and must be signed by a majority of the Council. If this notice is sent out as soon as possible after the meeting of the Council on January 22nd, the meeting to consider the question cannot be held until the third Wednesday in March, if it is to be a regular meeting of the INSTITUTE.

We recommend, therefore, that the regular meeting of the INSTITUTE, scheduled for Wednesday, February 19th, be postponed one week to Wednesday, February 26th, and that the question be submitted at said meeting.

The laws of the State of New York will make certain changes necessary in our Constitution, should we become an incorporated society. The consideration of these matters can best be postponed until after the question of incorporation is decided.

Your Committee is prepared to do all the necessary work pertaining to the incorporation of the Society, including the legal work.

The Sections of the Laws of New York relating to the matter are added as an Appendix.

An abstract of this report has been submitted to the non-resident members of the Committee, Messrs. Carhart, Hasson and Hibbard, whose names are signed to this report with their authority, thus making the report unanimous.

Very respectfully,

WM. B. VANSIZE, Chairman.
CARY T. HUTCHINSON, Secretary.
T. C. MARTIN.
TOWNSEND WOLCOTT.

By the Secretary.
A. S. HIBBARD.
W. F. C. HASSON.
H. S. CARHART.

January 21st, 1896.

The Secretary then read the following resolution :

Resolved, That the directors of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS be authorized and directed to incorporate such association, pursuant to Section 5 of the Membership Corporation Law, under Article 1 of such chapter, and to execute and file certificates and take such other and further steps as may be proper and necessary therefor.

THE PRESIDENT:—Gentlemen, the other societies are incorporated, and we are simply getting in line. There is no radical change to be made. Is that motion seconded?

MR. JAMES HAMBLET:—I second the motion.

THE PRESIDENT:—We will take this motion by a rising vote if you please. All the members in favor of the adoption of the resolution will please rise.

[Thirty-nine members rose.]

THE PRESIDENT:—All opposed to the motion will please rise.

[None rose in opposition.]

THE PRESIDENT:—The vote is unanimous. Our next business, gentlemen, is the continuation of the discussion of Mr. Sprague's paper on "Electric Elevators, their Uses and Advantages." According to the notice that was sent out, the discussion will be opened by Dr. Hutchinson, who is now making figures on the board.

DR. CARY T. HUTCHINSON:—Mr. President and Gentlemen, I propose to give to-night a short account of a test that I made on the elevator plant in the Postal Telegraph Building; a test of the energy expended in running the elevators for a certain definite time, under conditions of usual daily operation.

The plant, as has been explained, comprises six Sprague-Pratt screw electric elevators, two for express and four for way service. Current is supplied by a dynamo for this service alone, at a potential of 220 volts.

The test was made by connecting a Thomson recording watt-meter, bought for the occasion and newly calibrated, into the circuit of the six elevators. The readings of this watt-meter give the energy consumed. The travel of the cars was measured by putting a counter on each elevator. The counter was an ordinary bicycle cyclometer, connected so that each revolution of the fast-travelling sheave of the elevator moved the counter one tooth. The ropes lead directly from the fast-travelling sheave to the car; every revolution of the sheave meant a movement of about eight feet of the car; the counters were of course arranged so that they did not register backward; every car, no matter whether it went to the third story or the fourteenth story, registered its travel on the counters.

It was intended originally to have these tests extended over a week, but owing to trouble with the counters, to delay in getting the meter, etc., it was not possible to do this; so the record is for only one day's test, beginning at 10 o'clock in the morning and ending at 6 in the evening. Readings were taken approximately every hour. I believe that there will be no substantial difference between the results for one day and the results which would be obtained in a week's continuous test, at the same time of the year. There should be a difference between the result now, and the result at some different time of the year. The results from hour to hour are nearly the same. I have put a

table on the board, showing the travel of each car in miles, the consumption of energy for each hour, and the result of the whole day's run.

TABLE

SHOWING RESULTS OF THE TEST MADE ON THE ELECTRIC ELEVATOR PLANT OF THE POSTAL TELEGRAPH BUILDING.

Car No.	Car Travel in Miles.						
	9.45 A. M to 11.65 A.M	11.05 A.M. to 12.05 P.M.	12.05 P.M. to 1.00 P. M.	1.00 P. M. to 1.57 P. M.	1.57 P. M. to 2.57 P. M.	2.57 P. M. to 6.00 P. M.	Total for Day
1	1.76	1.14	.90	.97	1.10	3.32	9.19
2	1.72	1.10	1.10	1.01	1.10	3.94	9.97
3	1.72	1.27	1.10	1.12	1.23	3.85	10.29
4	1.78	1.05	—	.22	1.12	3.34	7.51
5	2.33	1.87	1.78	1.84	2.00	5.05	14.87
6	2.33	1.87	1.78	1.84	2.00	5.68	15.50
Total	11.64	8.30	6.66	7.00	8.35	25.18	67.33
K.W. Hours	49.2	34.3	32.9	32.9	37.	104.1	290.7
K.W. H.P. per Car Mile	4.23	4.14	4.95	4.70	4.33	4.07	4.37

Average speed, 350 feet per minute.
Car floor area, 33 square feet.
Average kilowatt-hours per car mile, 4.33.

There are six cars. Four cars stop at every floor; the others are express, stopping at 11th floor and up to the 14th. Three of the cars usually do not go above the 11th. The others usually go to the 14th. But all these variations are taken account of in the counters, which register the actual car travel, and are not based on any estimate of the average length of the trip. The cars run at an average speed of about 350 feet a minute; the area of the car platform is about 33 square feet. The general character of the installation has been dwelt upon, so it is not necessary to go into particulars.

One further point: Nos. 5 and 6 are the express elevators. In addition to putting counters on the car, I had the conductors register their trips. The counter of car No. 5 gave out after about an hour. In calculating the car travel of car No. 5, I have reduced the mileage of No. 6 in proportion to the number of trips as kept by the car men. The table gives, in the vertical columns, the actual mileage of each of the six cars for each

hour, beginning with car No. 1, 1.76 miles; car No. 2, 1.72 miles, etc., etc. The totals are given in the final column—car No. 1, 9.19; car No. 2. 9.97; car No. 3, 10.29; car No. 4, 7.51; car No. 5, 14 87; car No. 6, 15.50.

The next line gives kilowatts hours consumed, the total being 290.7, given in the column on the right. The total mileage for the six days for the day is 67.33, making the average kilowatt hours per car mile 4.33. The figure for kilowatt hours per car mile varies from hour to hour, on account of the different loads, from 4.07 to 4.95.

The test, I believe is as accurate as a thing of this kind can be made, without extending it over several weeks; it seem to give the results fairly of the actual practice in this particular plant under daily running conditions. I made all the observations myself, took all the readings, and connected all the instruments used; I believe the test is correct in the general result.

MR. J. W. LIEB, JR., (*communicated:*) As this discussion has raised the question of central station service, it may be in point to mention that of 13,395 H. P. on the N. Y. Edison system, approximately 5,000 H. P. are for direct connected electric passenger and freight elevators, of which there are over 500, probably more than 10% of all elevators in New York. Of these, 360, of about 4,000 H. P., have been installed within two years, of which approximately 200 (2,400 H. P.) were of Otis type; 70 (580 H. P.), A. B See; and 13 (250 H. P. Sprague, the others being of various kinds. In January alone, 50 electric elevators, of over 700 H. P., were connected.

The company has required that the inrush of starting current should not cause a variation in pressure of more than 3 volts above or 3 volts below the 120-volt lighting service, being 6 volts above or 6 volts below the 240 volts between outside wires, on which motors are usually placed. These conditions have, as a rule, been readily complied with by contractors, and the lighting service has compared favorably with that on systems not carrying a motor load. The large generating capacity of stations, and distributing capacity of street network, give central station service in this particular a decided advantage over isolated plants. In the one case, the effect of many motors is balanced and averaged to almost nothing; in the other case the starting of an elevator is shown directly on the lights, which has usually necessitated separate dynamos for elevator service in isolated plants. This seriously increases the investment cost and decreases the operating economy of isolated plants in comparison with central station service. The isolated plant, also, must have capacity to cover the maximum demand of the elevator, except in a building where many elevators are running simultaneously—again a disadvantage compared with the average demand on central station service. Finally, if the elevator service is to continue outside of usual hours, either the isolated plant must be run for excessive

hours at great sacrifice of economy, or a supplemental service must be obtained from central stations, or the elevators must be restricted to the stated hours, to the consequent discomfort and annoyance of tenants.

The price of current for elevator service has been kept at usual power rates—as low, for 1,500 H. P. hours per month, as 5c. per H. P. hour, $6\frac{7}{10}$ per K. W. hour. The intermittent nature of elevator service results in a much lower average return per H. P. from elevator motors than from almost any other class, the figures approximating from $18 to $25 per year per H. P. installed—a cost far below that of a power like steam, which must be kept on tap in the individual building to the extent of the maximum demand, and paid for accordingly. For this price service is available 24 hours for 365 days in the year. These figures and results compare rather well with isolated plants, when all the elements of cost are fairly considered—except in those extraordinary cases, rivaling Keely motor results, where, as in one instance, an engineer reported a cost of less than one cent per K. W. hour for electric current, and another lighted his building for "practically nothing." To enable owners to compare fairly, isolated plant costs with central station service, the Edison Company has recently prepared a blank for the use of owners and electrical engineers. From the data obtained in a recent case, it was found that a proposed building, requiring 5,000 lamps and 2,750,000 lamp hours per annum, would show an operating cost for isolated plant of $18,000 per year, while central station service at present rates would cost about $12,500. It may be added that, central station supply, with the double service usual in large office buildings, from two different mains, and with supply from the several Edison stations, gives a surety of resource not to be expected from an isolated plant, unless under exceptional conditions, and with the large additional investment necessary to give duplicate generating capacity.

Mr. George Hill:—Continuing my remarks at the last meeting, I desire to state that on page 12 of the paper, Mr. Sprague announces: "To meet the hydraulic machine, there "was designed and developed what is now known as the Sprague-"Pratt multiple sheave electric screw elevator. . . . . "This machine now stands the superior to the hydraulic elevator "in that it has speed and capacity, with, if anything, greater "safety and certain advantages in its automatics.

"On high lifts it occupies less space; it is more flexible in its "application, is more economical to operate and is more easily "cared for."

On page 22 he says that the Postal Telegraph plant is one to which this remark applies.

Mr. Sprague says that at a certain test of this plant 1,186 lbs. of coal were burned, but arbitrarily reduces the amount by 7 per cent., and then says $22\frac{1}{2}$ lbs. per car mile was the duty. You all

know that such a test must have been of relatively short duration; that estimating the condition of the fire at the beginning and the end of the test is very unreliable, and that there is an opportunity for grave errors to creep in; but in addition to this we are not given data as to either engine or generator size, as to time of the day, day of week, number of trips the car made, the number of stops the cars made, whether they were on regular duty or operating by running continuously up and down as rapidly as possible without any stops.

All of this data is necessary to form a correct idea of what can be done, especially when we consider that the amount of current required to start this machine is more than double its running current, and that consequently the power consumption per car mile for the same machine operated under the same conditions will vary almost directly with the number of stops made, increasing with every stop so as to nearly double the current consumption in service conditions over the amount required for exhibition-coal-per-car-mile purposes.

This ends his economy data.

Mr. Sprague gives a few words about tons of water lifted hundreds of feet, 2½ tons lifted 330 ft. per car trip and asks if this is economy. When reduced to H. P., this means 50 H. P. expended during the time occupied by a round trip for one car, regardless of the number of stops or loads.

Comparing this with the figures obtained by Prof. Shepardson at the Minneapolis tests of the screw electric machines, we have car lifting a live load of 2,500 lbs., (small load) 350 feet per minute (low speed), and requiring 52 electric H. P.

In this Shepardson record, no mention is made of the starting current required, so that we have at the beginning an expenditure of energy greater than the figures Mr. Sprague gives us, to which must be added the expenditure of energy required to start the car after every stop.

First: In a first-class elevator plant, there should be:

(*a*) Perfect regularity in car dispatching.

(*b*) No missing of landings.

(*c*) The highest speed the human system can bear.

(*d*) Perfect safety.

(*e*) Reasonable economy, both of capital and for operation as a part of a large plant.

The three first mentioned all have for a common object the delivery of the passenger in the shortest possible time.

The fundamental difficulties with the screw electric machine are:

I. The surge of current through the motor to overcome the inertia of the car is so great as to demand either storage batteries or two separate generating sets. This assertion is based on my experience with the drum electric machines (which require about one-half the current of the screw electric) at the Ameri-

can Book Company and the Jefferson Hotel. Observations of the Postal Telegraph plant, reports of the operation of the screw electric machines at the Hotel Grand (which, by the way, I am told is everlastingly in trouble), Minneapolis and Chicago, and ammeter readings on a dozen drum electric machines here in New York, and observations of the actions of the standard forms of direct connected generating units running underloaded, when suddenly loaded to near their capacity.

If this is not enough proof, visit any of the places where the screw electric machine is in use, and observe the variation in voltage when it starts.

II. The inertia of the car in stopping is constantly varying, since it depends on speed, weight and direction of motion, all of which are variants. The stop is effected by the short-circuiting device and the brake; the short-circuiting device requires time, and the brake having a constant retarding effect, requires a different length of travel to accomplish its purpose each time the conditions vary. As a consequence, either the operator must run with extreme caution, slowing up as he approaches each landing to prevent running past it, or else take the chance of missing the landing and running back to it, which involves a loss of time sufficiently great to permit him to have travelled through another story. This feature is so well known that even laymen mention it to me when I speak of electric elevators. I have observed it in the case of careless operators on every electric elevator on which I have ridden. The defect is inherent in the design of the machine, and increases in seriousness as the square of the speed, and, as a consequence, really high speeds will be found impracticable until a radical change is made.

This feature affects everything except the safety of the machine.

Mr. Sprague says (page 20) that his short-circuiting device can control the elevator, but you know that there must be rotation of the armature and consequently motion of the car for it to be effective.

This cannot be relied on alone, since any break in any circuit of the motor results in throwing it out of operation.

III. Concerning economy; in every first-class hydraulic plant the pumps work at a uniform rate. There are not less than six makers of pumps who will guarantee a duty of 30 lbs. of steam per pump H. P. hour. A plant consists only of pump, two tanks and connecting piping, and the elevator cylinder. The number of foot lbs. of work done by the pump, equals the maximum load multiplied by one half the number of feet travelled, divided by the efficiency, 55 per cent., and is a constant.

The experience of all of the makers tends to the belief that the cars average one-half the number of people lifted that they could lift, and consequently the expenditure of energy in lifting water is about 3.67 times that of the useful work done; but

having once stored up this amount of energy, there is absolutely no limit to the number of stops which can be made. This gives 110.10 lbs. as the steam per useful horse-power, and if the cars all ran fully loaded, this consumption would be halved.

In the screw electric machine, as I have before said, there is demanded either a special generating set or storage battery. For the generating set the engines would run under-loaded, demanding at least 60 lbs. of steam per indicated H. P. for one-half the work to be done, which, divided by the efficiency of the machine 51.3 per cent., gives 117 lbs. as the steam expenditure, plus an additional amount to be allowed for every landing made. This 60 lbs per indicated H. P. hour is based on my observations of about 300 cards taken from seven engines of capacities varying from 25 to 75 kilowatts, showing a steam consumption by computation from the cards, according to the Thompson method, of

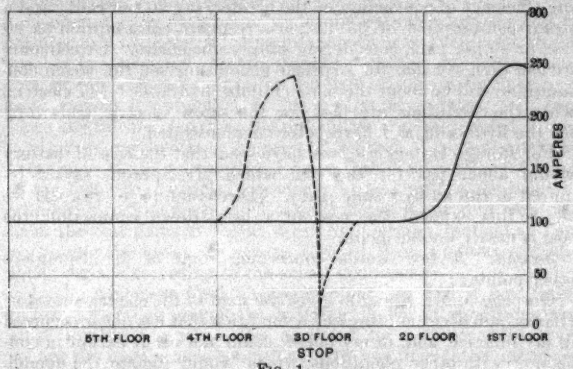

FIG. 1.

from 67 lbs. at 25 per cent. of rated capacity, down to 30 lbs. at rated capacity.

The influence of the number of landings made, and the care with which each stop is effected, has an interesting effect on the output, thus the current for one machine making a run of the entire travel with but one start would be as shown in Fig. 1. The hump must be repeated every time the car is started, and every time a landing is missed. Imagine the consequence on the area of the curve where a car is compelled, as in many of our buildings it is, to stop on an average of every other landing, both up and down. Our economy, as above stated, was for a single start. For the usual conditions the steam consumption must be very much increased.

If a storage battery is taken as the other alternative, an entirely new set of conditions arise.

In the first place we have the interest and maintenance of the battery to be charged against a saving of coal, and in the next place we must consider the efficiency losses of the under-loaded generator, charging the batteries through a booster, 3 or 4 automatic switches, etc.

In the case of the Postal Telegraph plant, to install a battery, allowing 15 per cent. for maintenance cost, depreciation and interest on investment, there would be a minimum charge of $3,000 per annum, or enough to purchase more than three tons of coal per day—rather a serious item.

Assuming that the storage battery is used, and admitting that by its use the coal consumption could be halved in so far as the storage of energy is concerned, we have to consider the watt efficiency of the battery, a matter of about 85 per cent., and, next, the efficiency of conversion of the booster, say 90 per cent., and a steam consumption of 35 lbs., or a resultant consumption of 90 lbs., or 20 lbs. gain, considering simply efficiencies. Of economy we can then say that for a special generating set, the steam consumption will be about the same (110 lbs. hydraulic—117 electric) when the conditions are best for the screw electric, and worst for the hydraulic, as I have before demonstrated.

For storage battery use, we have seen that the cost of battery would about pay for the coal which Mr. Sprague says is required to run an hydraulic plant. (Discussion page 26). If we add to this expense the cost of a break-down connection, the cost is nearly double again.

Second. A few words concerning some of Mr. Sprague's other points:

On page 5, Mr. Sprague gives the field of the electric elevator. His first sub-division brings up a condition that has never occurred in my practice, and, in my belief, could not occur except in connection with other conditions, which would dictate the demolition of the building entirely.

His second case I dispute.

His third case I cannot imagine as occurring, especially as I know of several cases where a change from a slow hydraulic to a high speed hydraulic was effected without interference with the service.

His fourth, fifth and sixth cases are perfectly met with the drum machine.

His statement on pages 9 and 10 is in my estimation unfair, since, as I have above stated, in a reasonably well designed plant, properly operated, there is a demand for a constant output of energy on the part of the pumps, and it is simply a question for the owner to determine between capital account and coal bills.

The statement on page 9 that fifty combinations of engines and dynamos demand less water evaporated than one hydraulic

pump is a fair sample of the statements made. Taking his own statement as to the steam consumption of a generating unit as given in the same paragraph, as less than 40 lbs., say 30 per H. P., and taking the efficiency of the combination as 95 per cent., we would have for fifty transformations 390 lbs. of water to compare with the 60 or 70 lbs. stated by him in this paragraph as the pump water consumption.

On page 10 he says the electric elevator used current directly proportioned to the work, modified in small degree by starting and slow running. I think, on the contrary, it would be more nearly the truth to say modified in an enormous degree by starting, slow running and number of landings.

The difficulties mentioned in the last two paragraphs of page 10 are, as far as my experience goes, fanciful, due not to difficulties inherent to the hydraulic elevator but simply to the disinclination on the part of most architects to be bound by limitations of any kind whatever.

Concerning the packing of hydraulic cylinders and the cost of maintenance of them, Mr. Sprague mentions isolated cases where trouble has occurred due to stupidity on the part of the operators, or carelessness or worse on the part of a shop foreman. A most cursory investigation of the hydraulic elevators will convince the fair-minded that the difficulties are exaggerated.

Mr. Sprague mentions the need of heating. I cannot speak for every consulting engineer, but I know that in my own practice one of the first points which I consider is the heat unit transmission of a building for the year, and I usually figure it out very carefully from the best plans available, using the German method and apportioning the losses per square foot of wall, window, roof and cellar surface according to the actual conditions.

In the American Book Company plant, we find it practicable to heat all of our part of the building under all conditions, and all of the three upper stories occupied by the University under all but the most severe conditions with less than three pounds of back pressure.

At the Odd Fellows Temple in Philadelphia, we heat under all but the most severe conditions, without one pound of back pressure, and without the use of live steam.

In both of these large buildings, there are two high speed hydraulic elevators operating constantly, during seventeen hours a day.

In a great many other plants that I know of, the daily coal consumption increases in the fall and winter as a regular thing, not because of the increase of lighting requirements, since my observations show it to vary with the outside average temperature rather than with the condition of the sky or ampere output, and I have the records of three large buildings to refer to.

Third. Let us refer to the Postal Telegraph plant:

Mr. Sprague, in his very interesting remarks, states that "in "the Postal Telegraph Building they are running more lights, "more car miles of elevator service, pumping more air, running "more motor converters, running more continuous hours of ser- "vice in a year than any building in the city of New York, "and running it on less coal than any building in the city of "New York for the same service"

This is a general challenge to produce any mechanical plant of nearly equal size operating as economically.

There is also the inference that this economy of operation is due to the use of the Sprague-Pratt screw electric elevator. I shall show that this is a very inefficient plant.

Recently it has been burning on an average of 7¾ tons per day of broken coal at $4.50 per ton. It has one generator running for electric elevator operation alone, in which the amperes vary from zero to 650. Volts vary from 190 to 245. The elevator speeds are about 275 feet per minute.

My authority for coal consumption cannot be divulged, but I pledge my word that you would unquestionably accept it if I should state it.

PHILADELPHIA RESULTS

Location.	Elevator.	Rise.	Trips.	Total Travel, Feet.	Car Miles.	Coal. Total Tons.	Coal. Per Car Mile, lbs.	Other Work.	Service.	Test Made.	Remarks.
Drexel Bldg.	1	60	603	72,360				One boiler running elevator pumps only.	Regular daily.	Every day conditions.	22,000 people carried as daily average.
	2	60	535	64,200							
	3	120	300	72,000							Net capacity of one car, 1,500 lbs.
	4	120	453	108,720							
	5	120	418	100,320							
	6	120	365	87,600	95.8	2.11	44.2				
305-307 Walnut St.	1	66	—	—		15 tons per month		House pump.			Capacity, 2,000 lbs.
	2	58	—	—							" 1,500 "
Trust Co. of N. America	1	77	250	38,500					Regular Daily.		Coal estimated by engineer, average.
	2	58	250	29,000	12.8	0.51	79.8	Supplied from one boiler.			
Land, Title & Trust.	1	78	300	47,800					Daily service.	Every day conditions.	
	2	78	300	47,800							
	3	95	150	28,500	23.2	0.47	41.0				

All are a good type of hydraulic elevator with the ordinary pumps, some compound and some simple, with no attempt made to secure high duty. A simple change in style of pump would reduce the coal per car mile to below 20 lbs.

RELATIVE FUEL COSTS.

FEBRUARY COAL BILLS.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Building.	Length.	Breadth.	Height.	Court Area Sq. Ft., Est.	Net Area.	Cube.	Tons Coal Daily.	Price.	Coal Cost per Day.	Hours Service.				Special Allowance, per cent.	Cube Cost.	Hourly Fuel Cost.			No. of Elevator.	Exposure.
										Act. Full.	Act. Partial.	Equi. Full.	Est. Full.			Per 24 Hours.	Column 14 Basis.	Column 13 Basis.		
Postal Telegraph Building ...	150	75	215	1,200	10,000	2.15	7.75	4.50	34.84	12	12	4	16	+ 10	16.20	0.67	1.01	1.12	6	S.
Home Life Insurance...	125	55	240	1,300	5,500	1.32	3.18	2.75	8.75	11	6	2	13	—	6.60	0.27	0.51	0.51	3	N.
" " "	—	—	—	—	—	—	4.75	2.75	13.05	11	6	2	13	— 15	9.88	0.41	0.76	0.64	—	—
Manhattan Life.....	115	66	260	1,000	6,400	1.66	6.50	2.75	17.90	11	13	4	15	— 20	10.79	0.45	0.72	0.57	5	N.
Mail and Express	Special.		140	780	7,900	1.10	4.00	2.75	11.00	12	—	—	12	— 25	10.00	0.42	0.83	0.62	4	N.
Morris Building.....	98	78	150	720	6,930	1.04	1.43	2.75	3.94	10	6	1.5	11.5	+ 25	3.79	0.15	0.33	0.39	3	N.
Am. Book Co..	180	98	160	923	16,700	2.67	3.50	2.75	9.64	12	—	—	12	— 15	3.60	0.15	0.30	0.25	7	N.
Odd Fellows Temple.	170	120	160	880	Sp.	2.17	3.22	2.75	8.85	18	—	—	18	— 20	4.08	0.17	0.23	0.18	2	N.

Cube stated in millions of feet. Cost in dollars per million cubic feet. Column 19 gives fairest comparison.

The Postal Telegraph Building is protected by the Home Life Building on the north. Its exposure is principally to the south, affording an advantage of 20 per cent. in heat required. The elevator service is not 24 hours a day for the entire plant, but that of a regular office building, with a few of the elevators, a portion of the lights, etc., run at night for the telegraph service. The building is very well lit naturally.

This coal consumption is for a very recent period. Mr. Sprague's figures, given after the conclusion of my remarks of an average from June '94 to December '95 of 6.2 tons, are the practical substantiation of the figures above given, because he gives us the average for two summers and one winter, starting from the time when the building began to be occupied. My records of plants show about the same proportionate increase between the daily average during the period for which I have made the comparison.

The Home Life Building is exposed on all sides, is very tall and has a tower, which I have not counted in making the cube. It has an expensive and extensive indirect heating system for the lower floors, three hydraulic elevators, is occupied as an office building during twelve hours of the day, with a supplemental service for five hours longer. I give two rates of coal consumption, the lower rate being for five degrees higher average temperature than was experienced during the time of the Postal Telegraph records under an exceptionally competent engineer, and the other taken at the same time that the Postal observations were made, and the work of a less competent engineer. My belief is that more than half of the difference is due to the difference in the men.

The Mail and Express Building is exposed, as you know, on all sides. In addition to heating the building, ventilating the basement with a large electric fan, ventilating the engine room with a large steam fan, operating four hydraulic vertical cylinder elevators, two hydraulic horizontal cylinder plate hoists, the entire lighting service of the building and the operation of the large Hoe presses required for the issue of the paper, considerable live steam is used in the stereotyping room for the driving of a small engine running eight hours a day, and for the heating of a building adjoining. The plant unquestionably could be materially improved; the daily coal consumption, however, shows remarkably well.

The Morris Building is strictly an office building, running at night for the convenience of tenants, as well as by day, has three hydraulic elevators and an independent electric lighting plant; coal consumption given is annual, averaged for a day.

The American Book Company building is ten stories, with cellar and sub-cellar, nine of the stories being occupied by the American Book Company factory, in which there are over 170 H. P. of motors, three large drum electric elevators, two hydraulic eleva-

tors of 450 per minute speed, one steam and hydraulic sidewalk elevator, a wasteful indirect heating plant for the roof, requiring live steam in severe weather in considerable quantities, a number of ventilating fans, etc. The hydraulic elevators are used for the service of the three upper floors, and are run constantly. Inasmuch as the shipping departments are on the third and fourth floors, and the manufacturing departments on the top floors, the electric elevators are in constant use all of the time. Two points are particularly noticeable. One, very moderate coal consumption, dropping to less than two tons of coal per day in the summer, and the other, the fact that the watt-meter records taken continuously day after day, one on the manufacturing circuit, which includes all fans, etc., and the other on the total power, which includes the first circuit and the electric elevators, are practically only 2.5 K. W. apart, with an occasional peak lasting but a second when two or more elevators happen to start together.

The Odd Fellows Temple is a large building, one-half occupied as offices, and the other half for Odd Fellows' meeting rooms, entertainments, etc. One of the courts only goes through five stories; the building is heated entirely by indirect radiation, a 120-inch Sturtevant fan being used occasionally during the daytime, and always during the evening in the summer. The building has two hydraulic elevators, besides its isolated plant, and runs continuously for eighteen hours a day. In the top floor there is a restaurant, which, the janitor claims, demands the expenditure of one ton a day alone for live steam for cooking, etc. The coal consumption stated is for the same period as the Postal, and is about the average in addition for the three winter months.

The Manhattan Life has 5 hydraulic elevators; one running twenty-four hours a day, has the Weather Bureau, which demands light and heat during twenty-four hours a day, and a seven-story tower, neither of which are figured into the cube, nor allowance made therefor. The regular office service is for eleven hours a day, and there is a supplemental service of thirteen hours. Coal consumption stated for the same period as the Postal. Elevator speeds are very much higher, and my belief is that the elevator car miles exceed those of the Postal by probably 30 per cent. Lighting requirements are undoubtedly greater, and the heating requirements certainly so, as the building is entirely exposed on all sides and is very lofty.

I have endeavored to make the table giving these results as complete as possible.

In the column headed "Special" I have made allowances in accordance with my own judgment, so as to reduce all to a uniform basis of hours of service. The two other columns of cost are figured from a perfectly evident basis.

Taking any one you please, the marked inefficiency of the Postal plant is evident.

In conclusion, I am fully alive to the shortcomings of the hydraulic elevator, have been fighting for years to obtain more efficient pumps in my plants, and to get a closer relation between the energy expended and the load lifted; but I do not see what road is open to secure the enormous advantage inherent in a hydraulic cylinder due to the fact that the acceleration of the car on starting does not derange the source of supply while in every form of electric elevator, this must occur. It can be handled in the drum machine, but not in the screw machine within any reasonable limits, and the final point, that the stop in the hydraulic machine is always positive, while in the electric ma-machine it rarely is.

Mr. John D. Ihlder:—I should like to call your attention to the difference between the screw machine and the ordinary drum machine. Mr. Sprague makes the claim that the screw machine is the only one that is fit for high speed service, and he bases his claim upon its special construction. Now, why an electric machine which has a rotary motion should be built on the same lines as a hydraulic machine which is reciprocating in its motion and has a short cylinder, and therefore must have multiplying sheaves, seems very strange. The screw machine of Mr. Sprague has, through these multiplication sheaves, an enormous pressure on the screw, which it seems he has overcome in a more or less satisfactory way, by making special tools, using special material, and large ball bearings, all of which are not necessary in the ordinary drum machine. The ordinary drum machine has the large advantage, again, of overbalancing. The screw machine cannot be overbalanced. In this way the drum machine reduces its duty down to less than one-half that of the screw machine, consequently the screw machine requires a very large plant for operating it, or has to use very heavy currents when it draws its power from the street. The difference between a balanced car and an overbalanced car is not very familiar to most of the members here. To illustrate this difference, take, for instance, a car of a duty of 2,000 pounds, with 400 feet speed. A drum machine can overbalance this load, if it is desired, to one-half, so that the duty of the machine is reduced down to 1,000 pounds. But the screw machine of Mr. Sprague's cannot only not overbalance the load, but, in order to start and accelerate the empty car on the down trip, is obliged to leave the car at the lowest figure 500 pounds, probably 1,000 pounds heavier, so that the duty of the screw machine is 2,500, or 3,000 pounds, instead of 1,000 pounds, for the drum machine. This is evidently a very great disadvantage against the screw. The only points that Mr. Sprague brings out to advance his claim that the screw machine is the only one that is fit for high speed are that it has a limited motion, and that the lead of the ropes is always in the same line; it does not shift as it does on the drum. Now, the shifting of the ropes on the drum is practically immaterial. It does not make the slight-

est difference whether the ropes vary, in their lead in 150 feet, something like two feet, or, when it comes to a 300 feet building, whether they vary something like four feet. The limited motion which is claimed as a parallel to the hydraulic machine is incorrect. However, there is practically no difference whether you consider a drum machine or Mr. Sprague's screw machine. Mr. Sprague tells us himself that it is impossible to suddenly arrest the motion of the screw. If you attempted to do it, something would break. There is so much power contained in the motor and the momentum of the car pulling ahead, that it would be impossible to suddenly arrest the motion. Consequently he must cut off the current and gradually produce friction, and in that way bring the car to rest. In its general features, the drum machine has the same arrest of motion. Most of the designs which are at present in use have a thread cut on the main shaft of the drum, with a traveling nut. It sets a train of gears in motion and cuts the current off, the same as the nut does in Mr. Sprague's machine, and puts a brake or some other arresting device on. So that the difference is practically only one in design; in theory it is exactly the same. Where the great difference exists that makes one machine fit for high speed service and the other not, I fail to see.

Mr. H. Ward Leonard:—I occupy rather a peculiar position. I do not think that the hydraulic machine has the superiority over the electric machine which has been claimed for it by its advocates. Neither do I think that the type of electric elevator which Mr. Sprague has described to us has the adwantages which he has claimed for it. But I do believe that the electric elevator in its best form has advantages over both the types that have been discussed. The hydraulic elevator has many features of disadvantage, which I think Mr. Sprague has put very forcibly. The Sprague electric elevator has a great many disadvantages which I think the hydraulic people have set forth very clearly. The desirable features for an electric elevator are that it shall be cheap as regards first installation; that it shall be cheap as regards operation; that it shall be possible to operate it at quite high speed under satisfactory control; that it can be stopped and started smoothly; that it can make a perfect landing; that it shall be quiet in operation; that it shall be simple in its essential parts; that it shall be clean, which is one of the points that is quite a factor in the office buildings of to-day, and in which electric elevators have a decided advantage over hydraulic elevators; that it shall restore useful energy in stopping; that it shall require but a small amount of power in starting—that is to say, a power which is proportional to the actual work without the necessity of the power which is absorbed and wasted in rheostats or any other starting devices of similar character;—that it should not affect electric lights which are connected to the same source; that it should require but a slight at-

tention to keep it in perfect order; that its cost, due to depreciation, should be small, and that the cost of power, in case power be purchased for operating it, should be small.

I believe that elevators running on my system of operating elevators have these features to a more marked degree than either the Sprague elevator or the hydraulic.

A statement of that kind carries but little weight, and I have not authoritative figures to substantiate it. But in case any person has a desire to investigate whether such a statement has any foundation in fact, I can refer them to the last installation, which is in Fahey Building, in Maiden Lane, where three elevators of the drum type are installed, and where we have no difficulty in operating to about the same height as the Postal Telegraph elevators. They have been in operation about three months. They start with a much smaller amount of power than any elevator that starts by rheostatic control or any other means. They do restore energy in stopping. They are perfectly noiseless in operation. The motion is perfectly smooth in starting and stopping. They make a perfect landing. The machinery is perfectly clean, and the speed is higher than the speed quoted for the Postal Telegraph elevator.

Mr. Franklin S. Holmes:—I have watched the Sprague elevator for some two or three years with much interest. I feel that any person who has the grit to build a machine on new lines and perfect it as that machine has been perfected is entitled to the thanks of the mechanical community.

But there seem to be two objections to the operation of a motor on these lines, and, indeed, to the electric elevator as it is now operated. The first is that we are taking a motor at its weak point. We take a motor standing still, and we ask it to lift a load at a speed equal to 400 feet per minute. Now, we know well enough that the current taken by a motor under these conditions is twice as great as the current required to operate it when in motion. Any machine that requires two or three times as much current to start it as to run it, simply because, or largely because, of a weakness of the machine itself, is fundamentally wrong. There are people who are now trying to make a combination between the hydraulic and the electric elevator thereby avoiding this weakness of the motor. In these days when pure breed is valued so highly, possibly such a mongrel as that is looked upon a little askance. But I believe that along these lines we shall, with direct current—I am not speaking now of alternating current apparatus—get the best results in elevator service. The objection which is peculiar to the Sprague elevator, it seems to me, is that it does not allow over-counterweighting. Mr. Sprague divided elevator work into two parts, namely, medium service and high duty service, and he claimed that the only elevator which can operate successfully on high

duty service was the screw elevator. I do not think that point was established. I think that the drum can be made serviceable for high duty service. The Sprague elevator takes about 200 amperes of current, I believe, to start, and a third of that, about 70 amperes of current, to run. The Otis elevator takes about 80 amperes to start and about 25 to run. Now, I have been on the platform of an elevator, where the armature was turning constantly, which took to lift three men, at the rate of 150 feet a minute, 30 amperes to start and 20 amperes to run, at 110 volts, which means 5 horse-power to start and 3 horse-power to run. This was under conditions when the current taken to come down was the same as that taken to go up. In other words, the thing was perfectly balanced. But that is the advantage you get when you have an armature that is turning constantly in one direction, and is one thing we are looking for. Such a machine will be commerical before a great while.

DR. HUTCHINSON:—Mr. Leonard says he has not figures to prove some statements about his elevators. If Mr. Leonard will give me permission to quote some figures that I have knowledge of, I will do so.

MR. LEONARD:—I do not know what the gentleman refers to. But any figures he has he is at liberty to state.

DR. HUTCHINSON:—I refer to a test of an elevator running in the Otis factory, when you were present.

MR. LEONARD—Do you refer to the apparatus you designed?

DR. HUTCHINSON:—No, I refer to the apparatus that the Otis company designed and use in their factory.

MR. LEONARD:—I was never present at any test where you were present except of an apparatus you designed.

DR. HUTCHINSON:—I beg your pardon; we ran a test in their factory on their motors.

MR. IHLDER:—I think we made a few tests. Possibly I have the records in my test books, and they are at your service.

DR. HUTCHINSON:—I do not want to give the figures without Mr. Leonard's permission.

MR. LEONARD:—I am perfectly willing that they should be given, with the explanation that they are not of the kind of plant that I mentioned when I spoke.

MR. IHLDER:—The figures taken there were from a dynamo driven by a motor, and then the dynamo drove the elevator motor; the plant which Mr. Leonard refers to has a dynamo driven by a steam engine. It leaves out the motor.

DR. HUTCHINSON:—Precisely; the steam engine takes the place of the first motor.

MR. IHLDER:—The steam engine takes the place of the motor. Those tests were made some time ago by students of the Stevens Institute, who will publish them in the near future.

DR. HUTCHINSON:—I am simply referring to tests that you were present at.

MR. IHLDER:—If you have any, they are entirely at your service.

DR. HUTCHINSON:—It is merely a question of the current required to run the intermediate dynamo and motor constantly, whether the elevator is moving or not. This work was done under your direction, and I shall not quote it except by your permission.

MR. LEONARD:—With the explanation I have made, you can give any figures you want to.

DR. HUTCHINSON:—The readings I am about to give were made on a slow speed drum freight elevator in the Otis factory. The car was driven by a motor of about 15 horse-power, to which current was supplied by a dynamo, which in turn was combined with and driven by another motor, supplied with current from the building circuit. The strength of the field of the dynamo, and consequently its voltage, was varied by rheostat, controlled by the operator on the car. The first motor and dynamo ran continuously during the hours of service of the elevator. In stopping, the elevator motor drives the dynamo as a motor, which in turn causes the first motor to act as a dynamo, thus returning current to the line

The readings were as follows:—

Current going up	20 amperes.
Current coming down	40 amperes.
Starting current	80 amperes.
Current when car was stationary	16 amperes.
Current returned to line in stopping, depending upon the suddenness of the stop, from 20 to 60 amperes.	

The average of the up and down current was 30 amperes. Of this, 16 amperes is required for the dynamotor. That is to say, over 50 per cent. of average power expended on the car is used in the controlling device. The actual running time of such a car is about one-fifth of its nominal operating time. With an elevator service of ten hours, 160 ampere hours would then be required for the dynamotor, and 28 ampere hours for moving the car. That is to say, of the total energy expended, only 15 per cent. goes to useful work, the balance being wasted in the dynamotor.

When a steam engine is substituted for the first motor, the case is worse, since a motor is a much more proficient piece of machinery on light loads than an engine.

MR. IHLDER:—I believe it is hardly fair to Mr. Leonard that this plant, which was run experimentally, should be quoted as giving exact figures.

It was a motor generator combination running 3,000 revolutions, which was put together by me out of machines which we happened to have in stock, in order to demonstrate that a speed of 3,000 revolutions was not desirable for elevator service. So they do

not show really any economy; they were not commercial machines.

MR. SPRAGUE:—Let us examine some of the statements which have been made. There have been six speakers.

Dr. Hutchinson has given some interesting figures bearing on the kilowatt hour expenditure per car mile of travel on the Postal plant between certain hours. These are interesting; but I think his conclusion that the average result would not be materially changed had the record been continued for a longer period of time is in error, as I will show later by some records of several thousand trips.

Mr. Hill has reproduced a good portion of my paper. I will later correct a number of his statements—some I shall ignore.

Another speaker, being somewhat timorous concerning electric elevators, advocates a mugwump system, a combination electric and hydraulic, having few of the good and most of the bad points of both. It might be pointed out that the ordinary motor pump and hydraulic elevator is such a system, but this is probably not the specific device which he has in mind.

Another sees great beauties in a type of machine which I am building, likewise the company which he represents, and exhibits a strange incapacity to determine differences between screw and drum machines which ought to be clearly manifest to any mechanical or electrical engineer.

Then again we have here the representative of the continuous operating system, whose advocate, contrary to one of his predecessors, believes in the supremacy of the electric elevator, so long as it is the particular type which he advocates.

Now, all these speakers are entitled, of course, to their respective views. It is true they are somewhat contradictory.

I will give a few facts now, and since the Postal Telegraph Building has been especially considered, I will take that plant.

First, I will state that there need be no mystery about the coal consumption. I have in my hand the operating log-book handed me to-day by courtesy of the attorney of the building. The coal burned for all purposes from June, 1894, to December, 1895, averaged $6\frac{1}{2}$ net tons instead of $7\frac{1}{4}$. This is the official record, and not one quoted without authority.

The comparison of other buildings mentioned with the Postal is of little moment unless it takes into account the real duty performed, and just here I will point out the fact that it is a continuous service building, and more so than any other office building in the United States, except the Western Union, which gets a part or the whole of its steam supply from the street mains.

A cubic contents unit comparison is simply misleading. The lighting of the Postal alone is a large factor, and although there are three dynamos, each rated at 72 kilowatts, for the lighting, telegraph and ventilation, recourse is had sometimes to the street for the telegraph supply.

Averaged for six months, January to July, 1895, the engineer's record shows an *average* for the above service for 24 hours, and for every day, of 356 amperes at 115 volts, or 982 kilowatt hours per day, and to give an idea of how steadily this demand holds up at different seasons we may note the hourly averages for each month as follows:

January	387 amperes.
February	370 "
March	368 "
April	348 "
May	338 "
June	335 "
July	345 "
Average	356 amperes.

As distinguished from the other buildings mentioned, the Postal has in addition to the continuous lighting service, and an actual, not janitor, night elevator service, a club and kitchen supply, and a telegraph and a pneumatic dispatch service.

If the whole building, except heating, was supplied from a central station, the demands would be about as follows:

Lighting and ventilation	808	K. W. hours, or about	52 per cent.
Telegraph	174	" "	11 "
Passenger elevators	350	" "	23 "
Water pumping	25	" "	2 "
Miscellaneous	180	" "	12 "
	1537		100 per cent.

These figures should speak for themselves. Since the plant is actually run locally on 6½ net tons of coal, then, assuming the coal distribution to be charged as per above percentages, 1.43 tons should be charged against elevators for each 24 hours, and it does its proportionate duty in heating.

It is, of course, difficult in a building which is always in use to make elaborate tests, but the following are submitted in addition to the above record:

The first is a coal record for the period beginning October 28th, 1894, and was made by Mr. Mackay's representative. The time was divided into three weekly parts. In the first week the entire service was supplied locally, in the second week the elevator service was supplied from the street, and the third week the entire service was again local.

Coal was measured by the number of loads of 2100 pounds each, and was as follows:

First week, 45 loads, local supply	94,500 lbs.
Third week, 48 " " "	100,800 "
Mean, first and third weeks, local supply	97,650 "
Second week, 43 loads, street supply	90,300 "
Average difference, one week, with and without local supply of elevator power, or 1050 pounds per day of 24 hours.	7,350 "
Maximum difference, one week, with and without local supply of elevator power, or 1500 pounds per day of 24 hours	10,500 "

The actual maximum record is about 50% of our estimate for the elevator service independently, that is, of 1.43 tons. This is probably in part because some live steam was used for heating the building, and because the boiler efficiency on a reduced power is a little less than when the elevators are running. It is interesting to compare this with the statement which was made by the Sprague Company as to what would be required in the matter of steam over and above the remaining service of a building in case electric elevators are used instead of hydraulics. There was made during the second week, November 3rd to November 12th, when the elevators were run from the street, 10,196 trips, a total travel of over 600 miles.

Our estimate was that the water evaporation would not exceed 250 pounds of water per car mile of travel. Six hundred miles would require an evaporation of not exceeding 150,000 pounds of water, or an average of 21,430 pounds per day. At eight pounds of water per pound of coal, which is a conservative rating of average boiler duty, this would be 2,680 pounds of coal per day as the maximum for this duty. Take another record, that of the Edison meter, for this same period from November 3d to 12th. This shows 3,108 H. P. hours charged. For 600 miles this would be almost exactly 5 H. P. hours per car mile of travel, or 3.80 kilowatt hours.

I see no reason to change my statement that on more modern plants the expenditure, averaged for all classes of service, will, with the average size of car, not exceed 3½ kilowatt hours per car mile.

On the night of November 22d, 1895, a test (to which expert engineers were invited), was made under the following conditions, in the presence of about twenty people:

All electric service, except elevators, shifted to street connection.

One boiler only left connected—B. & W.

All piping left in connection up to the engine and pump throttles.

Steam supplied to elevator engine, boiler and house pumps, and main pneumatic pump.

House pump prevented reliable use of water meter, but coal was accurately weighed, and nearly 2,000 electrical readings and the mileage of elevators were taken. One elevator was run on regular service, and five were run with 650 lbs. load (more than the average).

Boiler pressure	112 lbs.
Engine pressure	110 "
Pressure should have been	125

Exhaust into heating apparatus.

Westinghouse direct equipment used.

RESULT:

Duration of test, 9.30 P.M. to 12.40 A.M., 3 hours, 10 minutes.		
Number of round trips of 165 feet rise	744	
Total mileage	46½	miles.
Total coal burned	1163	lbs.
Less 10 per cent. for pneumatic and house service	116	"
Net coal for elevator engine	1047	lbs.
Coal per hour	331	"
Hourly mileage	14⅞	
Coal per car mile	22½	lbs.
Average kilowatts	54½	
Kilowatt hours per car mile	3.77	
Water at 8 to 1 evaporation per car mile	180	lbs.
" at 9 to 1 per car mile	204	"
" at 50 lbs. per kilowatt hour per car mile	188½	"
Average indicated H. P. of engine	82	
" " H. P. per car mile of travel	6	

It will be noted that the electrical expenditures per car mile of travel taken under actual service conditions for our work in 1894 and that just given under a test at fixed average load are almost identical.

Let us take another record, one interesting also because of the diversity of opinion as to the average live load. One says it is one-half, another one-fifth. Which is right? I have in my hand the record of 328 trips, in which every man, woman and child that got into or out of two cars in a ten-story building, the Board of Trade of Chicago, was taken. I submit for record three sheets taken at random. (See pp. 59, 60, 61).

The whole record is so long that I have not had time to average it, but it will bear out the statement which I have frequently made, that the average live load in a car does not usually exceed one-fifth of the normal maximum live load. In other words, if the car is rated at 2,500 pounds the average will not exceed 500 or 600. The meter record was taken of this same plant for the trips made, and shows an average of 4.1 kilowatt hours per car mile,—something over the Postal. Their cars are larger and heavier, and my guarantee was 4 kilowatts. Later it will run under the guarantee.

The Minneapolis plant I have never seen. The storage battery is being used because those locally in charge, at a time when I had nothing whatever to do with the installation of the plant, concluded that they would install a battery so that at certain hours of the day they could run their lighting and elevator service from one engine and the battery. I presume that is what they are going to do. The statement is made,—apparently gotten from newspaper clippings, that the machines at this plant are not up to guarantee. The test showed an apparent efficiency of 56 per cent., not 51 per cent., but it is probable that there was an error in the net weights reported, or some of the parts or the guides or sheaves may have been running hard, for they should have shown about 62 per cent. But this is not very important

PASSENGERS CARRIED.

Floor.	.....	1	2	3	4	5	6	7	8	9	Total In.	Total Out.	No. of Trip.
8.38 A.M.	Up.	11	....	....	1	....	....	....	....	....	12	....	28
"	Down.	....	2	1	1	2	....	2	2	4	....	12	"
"	"	....	..	....	....	....	....	....	....	....	0	....	"
"	Up.	....	....	....	....	....	....	....	....	....	....	0	"
"	Down.	10	....	..	....	....	....	....	....	....	10	....	29
"	"	....	2	....	....	....	1	1	3	3	....	10	"
"	Up.	....	....	1	....	..	....	..	....	....	1	....	"
"	Down.	1	....	....	....	....	....	....	....	....	....	1	"
"	Up.	7	....	....	1	....	....	....	....	....	8	....	30
"	Down.	....	....	....	1	....	1	2	1	....	....	8	"
"	"	1	....	..	..	....	1	....	....	....	1	....	"
"	Up.	3	1	....	....	....	....	....	....	....	4	....	31
"	Down.	....	....	....	....	1	....	1	....	2	....	4	"
"	"	1	....	....	1	....	....	1	....	....	2	....	"
"	Up.	8	....	....	....	1	....	....	....	....	9	....	32
"	Down.	....	1	....	2	1	..	1	....	4	....	9	"
"	"	5	....	....	4	....	....	....	1	....	5	....	"
"	Up.	11	1	....	..	....	....	....	....	....	12	....	33
"	Down.	....	1	....	3	....	2	....	2	4	....	12	"
"	"	1	....	....	....	....	....	1	1	3	5	....	"
"	Up.	4	....	....	....	....	1	2	....	....	....	5	34
"	Down.	..	....	....	..	....	1	....	....	3	4	....	"
"	"	....	....	....	....	....	....	....	....	....	0	....	"
"	Up.	10	1	....	....	....	....	....	....	....	....	0	"
"	Down.	....	1	....	2	....	2	2	2	2	11	....	35
"	"	4	....	....	....	4	....	....	....	....	....	11	"
"	Up.	6	....	....	....	....	....	....	....	....	4	....	"
"	Down.	....	....	....	....	2	....	....	....	4	6	4	36
"	"	....	2	3	3	1	4	....	1	1	15	6	"
"	Up.	14	....	1	....	....	....	....	....	....	....	15	"
"	Down.	8	2	..	....	....	....	....	....	....	10	....	37
"	"	....	....	....	2	2	..	2	....	4	....	10	"
"	Up.	5	1	1	....	1	..	....	....	5	7	....	"
"	Down.	12	....	....	....	....	....	....	....	....	12	7	38
"	"	....	....	....	....	3	1	3	2	3	....	12	"
"	Up.	....	....	....	2	....	....	2	1	....	5	....	"
"	Down.	4	....	..	....	1	....	....	....	....	....	5	"
"	"	8	3	....	....	....	....	....	....	....	11	....	39
"	Up.	....	2	..	1	1	1	3	....	3	....	11	"
"	Down.	....	....	....	4	2	....	2	....	3	11	....	"
"	"	9	1	....	1	....	....	....	....	....	....	11	"
"	Up.	12	2	....	1	....	....	....	....	....	15	....	40
"	Down.	....	6	....	....	2	3	1	....	3	....	15	"
"	"	1	....	....	....	....	....	1	....	....	1	....	"
"	Up.	7	....	....	....	....	....	....	....	....	7	....	41
"	Down.	....	5	....	1	1	....	....	....	....	....	7	"
"	"	1	1	....	....	....	1	....	....	....	2	....	"
"	Up.	3	3	....	....	....	....	....	....	....	6	2	170
"	Down.	....	....	....	....	1	2	2	1	....	....	6	"
"	"	....	....	2	....	....	....	1	1	....	4	....	"
"	Up.	1	3	1	....	....	....	....	....	....	1	4	171
"	Down.	....	....	....	....	1	....	....	....	....	....	1	"
"	"	....	2	....	....	1	2	....	....	....	3	....	"
1.12 P.M.	Up.	5	3	....	....	....	....	....	....	....	....	3	172
"	Down.	....	1	1	....	1	1	....	1	....	5	....	"
"	"	1	....	....	1	....	....	....	....	....	....	5	"
"	Up.	1	1	....	....	....	....	....	1	....	2	....	"
"	Down.	2	10	....	....	....	....	....	....	....	....	2	173
"	"	....	....	....	5	....	1	2	3	2	13	....	"
"	Up.	....	....	....	1	2	....	....	....	....	3	13	"
"	Down.	3	....	....	....	1	....	....	....	....	....	3	"
"	"	7	9	1	....	3	2	2	2	2	18	3	174
"	"	....	3	..	4	....	....	....	....	....	....	18	"

PASSENGERS CARRIED.—*Continued.*

Floor.	....	1	2	3	4	5	6	7	8	9	Total		No. of Trip.
											In.	Out.	
	Down.	....	....	....	....	....	..	....	....	..	0	....	174
	"												"
	Up.	6	10	....	....	....	..	....	....	....	16	0	175
	Down.	....	3	....	4	3	3	1	1	1	....	16	"
	"	....	2	4	2	..	....	....	....	5	13	....	"
	"	10	3										"
	Up.	9	6	....	....	....	....	....	....	....	15	13	176
	"											....	"
	Down.	..	..	....	4	2	1	4	2	2	....	15	"
	"	..	1	....	2	6	....	1	....	.	10	....	"
	"	7	3	....	....	....	....	....	....	....	....	10	"
	Up.	3	10	1	....	....	....	....	....	....	14	....	177
	"	....	....	....	4	6	2	1	1	....	....	14	"
	Down.	....	....	....	....	..	5	....	2	..	7	..	"
	"	4	3	....	....	....	....	....	....	....	....	7	"
	Up.	10	3	..	....	....	....	....	....	....	13	....	178
	"	....	2	....	....	4	....	3	3	1	....	13	"
	Down.	..	1	....	....	....	....	....	....	4	5	..	"
	"	2	2				1					5	"
	Up.	14	1	....	....	..	....	....	....	....	15	..	179
	"	....	....	....	1	4	3	2	2	1	....	15	"
	Down.	....	....	....	2	4	1	3	....	5	15	....	"
	"	9	4	2	....	....	....	....	....	....	....	15	"
	Up.	5	....	....	....	....	....	....	....	....	5	....	180
	"	..	..	..	....	3	....	1	1	....	....	5	"
	Down.	.	....	..	2	.	....	3	....	....	5	....	"
	"	3	....	..	....	....	2	....	....	....	....	5	"
	Up.	8	1	....	....	....	....	1	1	....	10	....	181
	Down.	....	2	....	....	2	2	2	1	1	.	10	"
	"	....	....	....	..	5	....	1	1	3	10	....	"
	"	7	2	....	....	....	1	....	....	....	....	10	"
	Up.	7	1	....	....	....	....	....	....	....	8	....	182
	Down.	....	1	....	1	....	1	2	1	2	....	8	"
	"	5	4	....	2	1	....	....	....	....	10	....	"
	Up.	4	....	....	....	....	....	....	....	....	....	10	"
	"	....	1	2	....	..	1	....	....	....	4	....	183
	Down.	....	....	....	....	....	....	....	....	..	....	4	"
	"	....	....	....	....	....	....	....	....	....	0	....	"
	Up.	..	....	....	....	....	....	....	....	....	....	0	"
	"	....	....	....	....	....	....	....	....	....	0	....	255
	Down.	....	....	....	....	....	....	....	....	....	...	0	"
	"	....	....	....	....	....	....	....	....	....	0	....	"
	Up.	4	....	....	....	....	....	....	....	....	....	0	"
	"	....	1	....	....	....	....	1	2	....	4	....	256
	Down.	....	1	..	2	....	....	1	1	....	.....	4	"
	"	5	....	....	....	....	....	....	....	....	5	....	"
	Up.	2	....	....	....	1	....	1	....	....	....	5	257
	Down.	....	....	....	1	....	1	....	....	1	3	....	"
	"	..	....	....	....	....	....	1	1	....	..	3	"
	"	2	....	....	....	....	....	....	....	....	2	....	"
	Up.	3	....	....	....	....	....	....	....	....	....	2	258
	"	....	....	....	2	....	....	1	....	....	3	....	"
	Down	....	....	..	....	....	....	1	....	....	....	3	"
	"	....	1	....	....	....	....	....	....	....	1	....	"
	Up.	2	1	....	....	....	....	....	....	....	...	1	"
	"	....	1	....	....	1	....	1	1	....	3	....	259
	Down.	..	2	....	2	....	2	1	....	....	....	3	"
	"	6	....	....	....	....	....	....	....	....	6	....	"
	Up.	2	....	....	....	....	....	....	....	....	2	....	260
	Down.	....	....	..	1	....	....	....	....	1	..	2	"
	"	....	....	....	....	1	2	1	....	1	5	....	"
	Up.	4	1	....	....	....	....	....	....	....	....	5	"
	"	4	....	....	....	....	....	....	....	....	4	..	261
	Down.	....	....	....	1	1	1	1	....	....	....	4	"
	"	2	....	....	....	1	....	....	....	2	3	....	"
4 to P.M.	Up.	2	....	....	....	....	....	....	....	....	2	3	262
	Down.	....	....	....	....	....	1	....	1	..	..	2	"
	"	....	....	....	....	....	....	....	....	....	0	....	"
	Up.	3	..	....	....	....	1	....	....	....	....	0	"
	"	..	....	....	....	....	....	2	2	....	4	....	263
	Down.	....	....	....	4	2	1	....	....	....	8	4	"
	"	7	1	....	....	....	....	....	....	....	....	8	"

PASSENGERS CARRIED.—*Continued.*

Floor.	.....	1	2	3	4	5	6	7	8	9	Total In.	Total Out.	No. of Trip.
	Up.	3	.....	...	...	.....	.....	.....	.....	.....	3	.....	264
	"	...	1	...	.....	2	.....	.....	.....	.....	.....	3	"
	Down.	.....	.....	.....	1	1	.....	2	.....	1	5	.....	"
	"	4	1	.....	.....	.....	.....	...	.....	.....	.....	5	"
	Up.	3	.....	.....	.....	.....	.....	.....	.....	.....	3	.....	265
	"	...	.....	1	1	.....	.....	.....	.....	1	.....	3	"
	Down.	.....	.....	.....	...	1	.....	.....	1	.....	2	...	"
	"	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	2	"
	Up.	3	.....	.....	.....	1	1	.....	.....	.....	3	...	266
	"	...	.....	1	.....	1	1	.....	.....	.....	.....	3	"
	Down.	...	.....	.....	.....	.....	.....	2	.....	.....	2	.....	"
	"	2	.....	.....	.....	...	.....	.....	.....	.....	.....	2	"
	Up.	1	.....	.....	.....	.....	.....	.....	.....	.....	1	.....	267
	"	...	.....	.....	1	.....	.....	.....	.....	.....	.....	1	"
	Down.	...	...	2	.....	.....	.....	2	4	.....	8	...	"
	"	7	1	.....	.....	...	.....	.....	.....	.....	.....	8	"
	Up.	3	.....	.....	1	1	.....	.....	.....	.....	5	.....	268
	"	...	.....	.....	1	..	.....	.....	.....	4	.....	5	"
	Down.	.....	.....	.....	1	.....	2	1	1	.....	5	.....	"
	"	3	2	.....	.....	.....	...	...	.....	.....	.....	5	"

at the present juncture, for I hold in my hand the full copy of Prof. Shepardson's report, and I quote verbatim the closing paragraph as follows:

"The meter was put in circuit Wednesday evening, January "1st, 1896, at 6 P.M. Readings were taken each day at the same "hour. At 6 P.M. Saturday, January 18, 1896, the meter "showed that 1129.2 kilowatt hours had been used by the three "elevators in seventeen days. At the same rate, 1994 kilowatt "hours would be used in a month of thirty days. At the regular "motor rate of 7½ cents per kilowatt hour charged by the Minne- "apolis General Electric Company, this would come to $149.50 "per month. The discount of 35 per cent. for monthly bills be- "tween $100 and $150 would reduce this to $97.17 per month "for the three elevators for one month, or about $1.08 per ele- "vator per day. This remarkably low cost of power actually "used, shows the wisdom of your board in adopting electric "power for your elevators."

The plant is to be extended.

The Chicago Board of Trade plant is under the supervision of Mr. B. J. Arnold, a member of this INSTITUTE. The storage battery will be put in there because Mr. Arnold made the statement to this Board of Directors that with a single engine driving a 75 kilowatt dynamo he could run the four large elevators, a number of ventilating motors, and lights, both arc and incandescent, for a certain number of hours, and after that run entirely from the storage battery. It is not my province to criticise this plan or conclusion.

At my own works, I am about trying a storage battery, but not because we are in any danger of breaking down, especially as we have a duplicate equipment, but because I wish the facts.

Ground for criticism has been sought in the fact that the Postal has a street connection. That is a very sensible practice. They happen to have a good many motor converters which required absolute certainty of delivery of current for twenty-four hours for their telegraph service. Electric elevators at one time were not looked upon with general confidence, and there was opportunity for serious delays and troubles in starting so new a plant. Then, too, they wished to know if perchance it might be more economical to run from the street than from their own plant and as a wise provision, which people, under those circumstances would naturally make—it is now some two and a half years ago —they put in break-down switches connected to both the 240 and 120-volt circuits. I think that was an ordinary precaution.

A passing comment upon the report of the Edison company is not out of place. The screw machines, which are the specially characteristic machines built by the Sprague company, are generally operated from large isolated plants and not from the street, because individual elevator and light duty service has not been sought by it. That, of course, anyone can do without trouble My aim has been to surpass the hydraulic service in its highest type, which is almost invariably operated by private plants.

With regard to the criticism that it takes more current to start a gravity machine than an over-balanced machine, that goes without saying, but the reasons for using gravity control on the screw type of machine will be set forth later with reasonable fullness.

The statement that it requires 200% or 300% more to start a machine than to run it will not stand present investigation. In past work, there have been times when there has been from 100% to 200% excess of current used momentarily, not because the machine required that to start it, but because the resistance has been cut out of the circuit at a rate in excess of the building up of counter electromotive force. That objection has been done away with, and with the small amount of static friction it is possible to start a screw machine with a very small percentage above the actual running current, this depending upon the amount of counter-weighting carried, the speed at which a car is intended to be run, the load carried, and the rate of acceleration.

It is now perfectly possible automatically to control this starting current so that it will not be over 25% or 50% or any other percentage above the running current, and this method of operation does not interfere with the lights on a large central-station circuit.

We have gone so far even as to now run elevators during a good portion of the day on the same engine as the lights of the building, as in the Hotel Walton, Philadelphia, and this practice will grow rather than decrease, because of certain features which it is my privilege to introduce. I state without reservation that such potential variations as are given for the Postal plant do not

occur, nor can they occur, except under the most abnormal conditions and with engines and dynamos of the poorest character.

Mr. Hill quotes my statement that "measured by standard "practice, a given number of pounds of energy can be delivered "to the controlling apparatus of an electric elevator for less "pounds of steam, that is, water evaporated, through the medium "of no less than fifty combinations of engines and dynamos than "can be delivered to the valves of any hydraulic cylinder through "the standard pumps permissible in average elevator practice," and indulges in a curious mathematical flight wherein he gets lost in combinations and permutations. He says that this is a fair sample of the accuracy of the statements contained in my paper. I am glad to hear that frank acknowledgment, and it is fair to say that his criticism of it may be taken as the measure of his criticism of the balance. It would seem that my original statement was quite clear. Put in a different form, it is simply saying that there are no less than six or seven standard dynamos, and not less than seven or eight excellent engines, any one of which dynamos and engines can be employed, and by this combination energy can be created as stated.

Mr. Hill distorts this statement into the absolutely absurd conception that there may be fifty *transformations* of energy, and that a high percentage of return can still be obtained.

Now, as regards automatic control, I repeat, that in a hydraulic system the character of automatic control used on my electric elevators as it is practiced, is not feasible where a mechanical operating pilot exists, and if any device is applied to the pilot valves of the hydraulic elevator, to be effective in this way, it must be electric. Its use requires the operator to keep his hand on the lever under all conditions of car movement, and operates to cut the current off instantly in hoisting, or to bring the car to a prompt stop in lowering, in case the operator is negligent or is pushed away from his lever, or in case any accident happens to him. This control is not on other makes of machines of any kind or description, and in case of an emergency it is of the most vital character.

It is odd that some of the speakers have fallen into the mistake of assuming that we do not know exactly what our machines are doing, or what, with the improvements we are introducing, they can do. They also differ somewhat as to the relative costs of electric and hydraulic plants. My statement is entirely sound, that, measured by the prices which have obtained in this city for first-class hydraulic elevator plants, the electric equipments have been the less expensive plants to install, and even with the increase of generating plant are not necessarily more costly.

Generally speaking, on large loads the total efficiency of a screw machine will vary from 60 to 68 per cent., and on a drum machine from 40 to 68 per cent.

The best practice of governing over-balanced drum machines is

the use of a rheostat in the armature circuit up to one-half speed, and then the weakening of the field, exactly as I did on the elevated railroads some ten years ago.

I am not proceeding in ignorance of the physical laws covering the operation of electrical machinery. I try to meet all the conditions which arise in elevator service, not simply selected ones,—and no man in dealing with human life is justified in ignoring the abnormal conditions which may arise,—the failure of current, of a brake, a cutoff, breaking of a shunt field wire, slipping of a brake, running away of the machine, or the carelessness or ignorance of an engineer or an operator. All machinery, we may say, when operating normally operates with safety. What we are more concerned about is what will happen when conditions in an emergency are abnormal.

I have no apology to make for my strictures upon the drum machine, no matter by whom made. I say that up to certain speeds, and under certain conditions, it is the proper machine to use. Under certain other conditions and more extreme speeds it absolutely is *not* the proper machine, and I say further that any machine which has not got the power of self-excitation in case of emergency should not be tolerated on serious passenger work. I want to emphasize this fact just as plainly as I know how.

It is curious to hear the claim that a drum and a screw machine are practically the same, and it can only be accounted for by either a wilful disregard of facts, or because of ignorance of the essential principles of construction and control. I shall try to make the differences clear. There have been in the past two forms of hoisting machines,—one the steam worm gear drum elevator, the other the hydraulic, either vertical or horizontal. The hydraulic has had the preference over the drum machine in the matter of first-class service, and in point of safety.

Electric elevators are likewise of two types, the first being the drum—that is, the absolute counterpart of the steam drum machine, subject to its limitations and modified by the replacement of a steam engine by an electric motor. The second is the electric counterpart of the hydraulic macine, having all its "safeties," and something more than its safety. As I have stated, I build both types of machines, but I classify the duty to which, according to my judgment and experience, and that of engineers in general, they should be applied.

The drum machine is always subordinated in the class of work to which it is applied. It is not deemed by hydraulic companies nor by myself, the equivalent of the hydraulic elevator for first-class service, although the drum machine I am building has, for example, six times the gear surface under pressure of many machines. Its strength and efficiency in this way are materially increased. It has not, however, the elements of absolute safety which characterize the screw machine, and which will

relegate the hydraulic elevator to a subordinate position. In general:

The drum machine corresponds to the steam drum machine, long since given the second place.

The screw machine corresponds to the very best type of hydraulic elevator.

There are detail points of differences on these two types of machine,—differences which I consider absolutely essential on first-class passenger service:

1. The screw machine has absolute limits of travel.

The drum machine, on account of the endless character of its mechanical movement, has no fixed limits of travel.

It is therefore impossible to drive a screw machine into the overhead timbers, or send it into the basement by failure of the cut-off and brake. This has never happened to a screw machine. It can, and has happened to a drum machine.

2. The screw machine not only has the normal cut-offs and brakes, but, on the up movement, the mechanical part absolutely dislocates in case the cut-off fails to work, and it has, at the lower end, a buffer nut, which will stop a car going 600 feet a minute without danger, in case every automatic should absolutely fail.

The drum machine does not have, and cannot have, either one of these mechanical limit automatics.

3. The method of control on the screw machine makes it self-exciting, both in normal operation at its lower limit and in the event of failure of the main current.

The drum machine control generally adopted, that is, where over-balanced, is such that the machine cannot be self-exciting.

The power of self-excitation, the impossibility of demagnetizing the machine, and the fact that the current in the machine is never reversed, are essentials in the matter of safety under certain conditions of failure of current and brake, because the machine develops automatically a dynamic-brake of the most powerful character.

4. At least four hoisting ropes are used on a screw machine, and from five to six car and counter-weight ropes. The ropes at the hoisting machine have fixed leads, and are equalized on each side. The ropes on the car pass over one set of overhead sheaves, and each rope has equal duty under all conditions.

On a drum machine it is difficult to use more than two hoisting ropes, or at best three. They cannot be equalized at the machine. They have a shifting lead, and under certain conditions they are apt to jump the grooves. If the cars go to the basement, the back counter-weight ropes which must be there used are "broken-backed." There are three sets of overhead sheaves, and three different sets of ropes under unequal duty.

5. In addition to the "safeties" which characterize hydraulic chines, the screw machines carry a "centrifugal automatic" at the machine which prevents intentional racing of the car by a

careless operator, and can, if desired, make the machine a self-exciting dynamo on a closed circuit.

6. The screw machine can be built for any desired load or speed, for it is impossible to drive it past its automatics more than a fixed distance. It works on the gravity principle, precisely as the hydraulic does, and on that account has certain safeties not applicable to any other machine.

The drum machine should not be built for speeds higher than 300,' because it has a carrying-by power on account of the greater masses in motion, rapidly increasing with speed, which render it liable to run into the overhead sheaves or into the basement in case of failure of cut off at a critical moment.

I hope I have made clear the differences in the two types of machines. Practical experience confirms my impression as to the importance of these essentials.

The tangible fact remains that, although electric elevators have been used for twelve years,—I put in one in the Pemberton Mills, Lawrence, Mass., in 1884,—it was not until the screw machine was developed that the hydraulic system was brought face to face with a real competitor. Its makers recognize that fact now.

Much has *not* been said by those who have been speaking upon the subject of hydraulic elevators, so I will make reference to two plants. The first is that of the Masonic Temple Building of Chicago, and it is interesting to note the opinion of the Chief Engineer of the Crane company, who, on the 10th of May, 1895, sent a report to the Vice-President of the Crane company, from which I quote verbatim as follows:

"DEAR SIR:—

"Below you will find data as to the Hale elevators and "Worthington pumps as now operated in the Masonic Temple "Building, this city.

"The conditions under which the observations were made were "those in every day practice, no notice of preparation being given "that such observations were to be made.

"The observations began at 7 A. M., May 8th, and continued "uninterruptedly until 12.10 A. M., May 9th, so as to take in one "complete day's service of the elevator plant.

"Registers were placed upon the pumps so as to record each "stroke made, and watch was kept upon the elevators and the "trips made by all of the elevators during the day were noted. "The notes and figures give me the following results:

"The elevators consumed 612,166 gallons of water, and the "pumps delivered 1,469,722 gallons in the same time, showing a "discrepancy between the gallons of water supposed to be deliv-"ered by the pumps and the amount of water actually displaced "by the movement of the elevator pistons of 59%. In other "words, without taking into consideration whether the pumps "are the best that could be used for the purpose, or whether the

"elevators are the best that could be used, these figures establish "the fact that more than one-half of the coal now burned is ab- "solutely thrown away and is burned for no useful purpose "whatsoever, so far as running of the elevators is concerned."

This is followed by the usual modest claim that by a change in the hydraulic method of operation there can be a saving of nearly seven-eighths in the coal consumption.

Careful avoidance is made, I notice, of mention of the American Tract Society's plant, put into operation in May of last year, and supposed to represent the highest result of the combined skill and talent of the engineers of one of the most prominent elevator companies in this country,—a plant installed in full recognition of the fact that the hydraulic elevator, as commonly built, no matter whether for high or low pressure, uses identically the same amount of power for every foot of travel with or without a load. In this particular plant inverted differential piston cylinders are used, originally designed to work at about 750 pounds pressure, and to use water on one side of the piston when more than a certain load is carried, and on both sides on a differential plan on a light load.

The architects' requirements were that one car should make 700 ft. and five cars 600 ft. per minute, that they should make 1,200 round trips at full load in ten hours, and the guarantees by the hydraulic people were 1,750 lbs. of coal per day.

That building is reported to have practically abandoned the essential economic features of the plant. Pressures have been materially raised; the pumps and accumulators are disproportioned; a by-pass has been introduced in the high duty pump to prevent its sticking; the differential valve has been largely inoperative; the speeds guaranteed are not made; the loads called for are not lifted; the trips specified are not recorded. The building, while averaging for 24 hours less than one-half the lighting of the Postal Building, which has in addition its telegraph and pneumatic service and carries more people per day on its elevators, is burning not less than eight tons of coal per day, and it is stated that at times it goes as high as nineteen tons. I have not had an opportunity to verify the statement of the engineer, but I think these statements will be found to be pretty close.

Did time permit, I might add further pertinent reports, but these will suffice. I thank you, gentlemen, for your attention.

[Adjourned.]

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